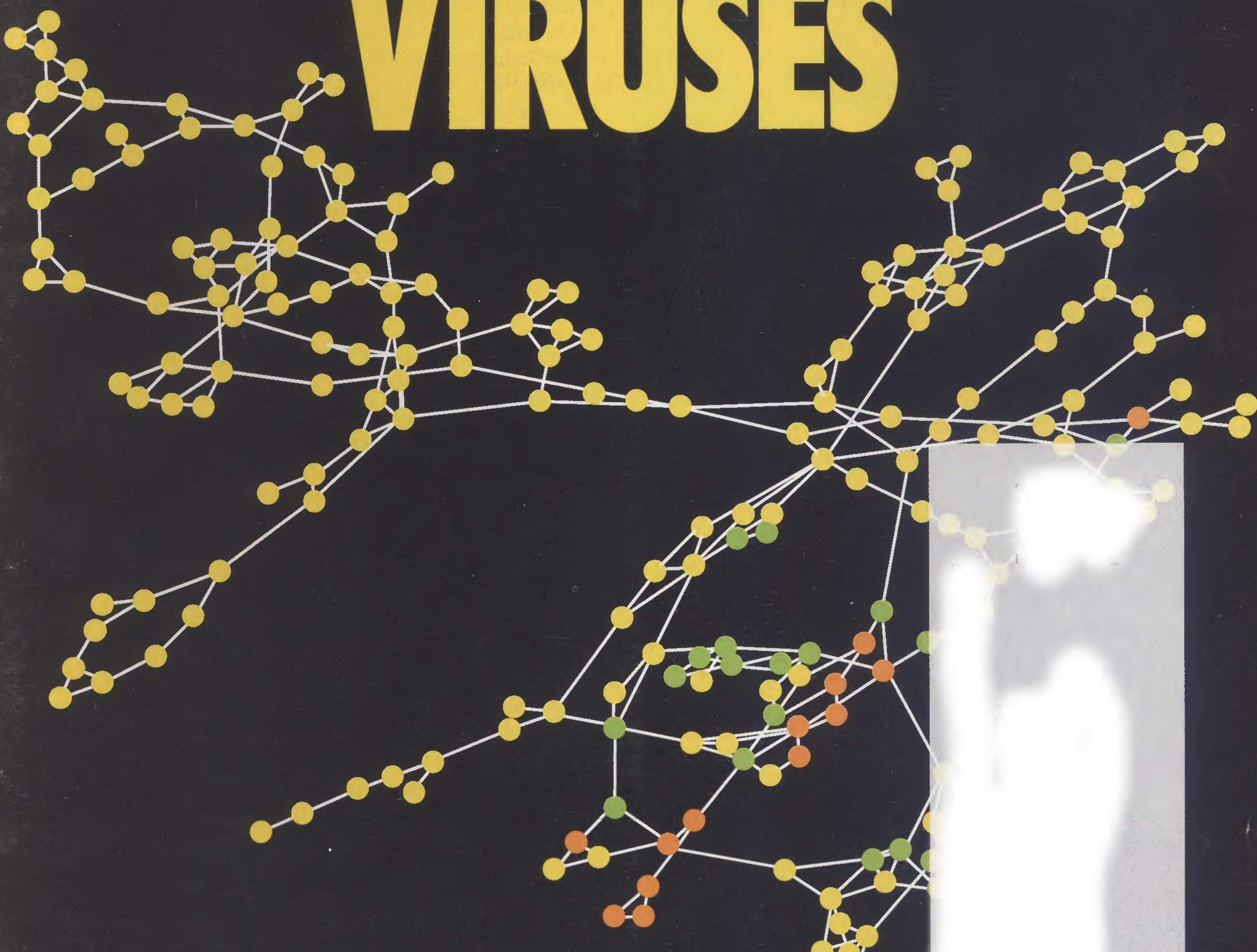
SPECIAL GUIDE: WORKSTATIONS AND PCs, P. 35

IEEE
SPECTRUM

COMPUTER VIRUSES



MAY 1993 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Newslog

MAR 9. Japan's Vice Minister of International Trade and Industry said Japanese companies were to be criticized for not mastering critical technologies like microprocessors and computer workstations. He said Japan's economic woes were due to adding too much factory capacity and giving too little thought to future technologies.

MAR 10. The Czech government said it had given the go-ahead for completion of the US \$2.2 billion nuclear power plant at Temelin in southern Bohemia. Its completion had been strongly opposed by local environmental groups and by neighboring Austria. **From Westinghouse Corp.**, Pittsburgh, will come high-quality fuels and new control systems to upgrade the plant to western standards.

MAR 11. Groupe Bull SA, Paris, said it had licensed its patented IC card technology to five Japanese companies, including **Toshiba, Hitachi,** and **Oki Electric.** Analysts said the IC market in Japan is expected to grow to 1–2 billion yen.

MAR 16. Digital Equipment Corp., Maynard, Mass., announced that **Mitsubishi Electric Corp.**, Tokyo, will become its partner in building and selling DEC's Alpha AXP microprocessors. Under the pact, Mitsubishi will also have the right to produce and sell chips that are variations of the Alpha design. DEC wants to make Alpha an industry standard for chips based on reduced-instruction-set computing technology.

MAR 17. Six computer companies, including **IBM, Hewlett-Packard,** and **Sun Microsystems,** announced a common software standard aimed at stepping up the use of computer networks based on the Unix operating system. The common approach—also agreed to by **Novell, Santa Cruz Operation,** and **Unix System Laboratories**—will enable Unix applications to look and work the same on different computers.

MAR 17. Intelsat said it is planning to lease space on three new Russian satellites to be launched next year by **Informkosmos.** The global satellite consortium faces a worldwide shortage in satellite capacity plus competition from undersea optical-fiber lines and new satellite rivals. The Russian spacecraft will provide telephone, voice, and data communications.

MAR 23. The chief executives of the leading **U.S. local and long-distance telephone companies**—in a rare display of unity—said they had called on **President Clinton** to let private companies build and manage most of a proposed national high-speed optical-fiber network. The group also called for Government subsidies to help develop such a network.

MAR 24. President F.W. de Klerk announced that nuclear weapons had been developed and produced by **South Africa** in the late 1970s, but had been dismantled after he took power in 1989. He said all hardware and all design information used in the bombs' construction were also destroyed.

MAR 30. The **U.S. Environmental Protection Agency** (EPA) said its first auction of rights to pollute the air had reaped \$21 million. For the 50 000 spot allowances the EPA offered, 106 bids were received, 36 of which were successful. The EPA had earlier granted emissions permits to 110 of the largest sulphur dioxide polluters, mostly coal-burning electric utilities; the companies may trade any excess permits they hold.

MAR 30. The **United Kingdom's National Grid** and **Ireland's Electricity Supply Board** said they will build a £300 million high-voltage link under the Irish Sea. The 600-MW cable will connect the Irish grid to the rest of Europe for the first time and could also provide a market for the UK's coal-fired power stations in the late 1990s. The grids of Northern Ireland and the Irish Republic have been isolated since the 1970s when the interconnector was shut down after repeated attacks by the Irish Republican Army.

MAR 30. AT&T Co. said it had won a \$100 million contract from the Polish telephone company, **Telekomunickacja Polska,** to supply equipment to the northern city of Gdansk. The contract is for 200 000 digital lines as well as for optical transmission systems, network management systems, and fiber cable equipment.

APR 1. Intel Corp., Santa Clara, Calif., said it would spend \$1 billion to expand its semiconductor fabrication facility in Rio Rancho, N.M., adding over 121 000 square meters and creating 1000 new jobs. Work on the expansion will start immediately, with production of Intel's new Pentium chip scheduled to begin there in 1995.

APR 5. The **New York State Thruway Authority,** Albany, said that Dallas-based **Amtech Corp.'s** electronic E-Z Pass toll-collection system will be the first to be installed on the Governor Thomas E. Dewey Thruway outside New York City and Buffalo. E-Z Pass, which began testing in January, is to be part of a \$150 million toll system that will allow New York, New Jersey, and Pennsylvania drivers to pass through toll stations without stopping.

APR 2. New Valley Corp., the former **Western Union Corp.**, said that it had filed for protection under Chapter 11 of the U.S. Bankruptcy Code after it had been unable to reach an agreement with its debtholders. The company said it had total liabilities of \$800 million and total assets of about \$150 million.

APR 2. Westinghouse Electric Co., Pittsburgh, said it had signed a contract with **Advanced Reactor Corp.**, a U.S. utility consortium, to invest \$158 million over five years in developing a safer, standardized design for a 600-MW pressurized-water reactor meant for nuclear power plants. Also participating are the U.S. Department of Energy, several U.S. nuclear contractors, five U.S. and Canadian universities, and utilities and agencies in Japan, Spain, Italy, and Indonesia.

APR 5. South Korea's **Daewoo Group** said it would invest \$1 billion in a joint venture with **Tatarstan's Yelabuga** motor factory for a car plant and factories to assemble South Korean video and audio equipment. The equipment would be sold in Tatarstan, an autonomous republic within Russia, and elsewhere in the Commonwealth of Independent States.

APR 5. President Fidel Ramos of the **Philippines** said he had signed a bill giving him emergency powers to deal with the many electric power shortages—some lasting 6 to 8 hours daily—that have disrupted the country's economy. The new law allows the president to negotiate contracts for building new plants, instead of going through the legal bidding process. The move is expected to spur a 1600-MW expansion of the Luzon grid, which services Manila and nearby industrial centers.

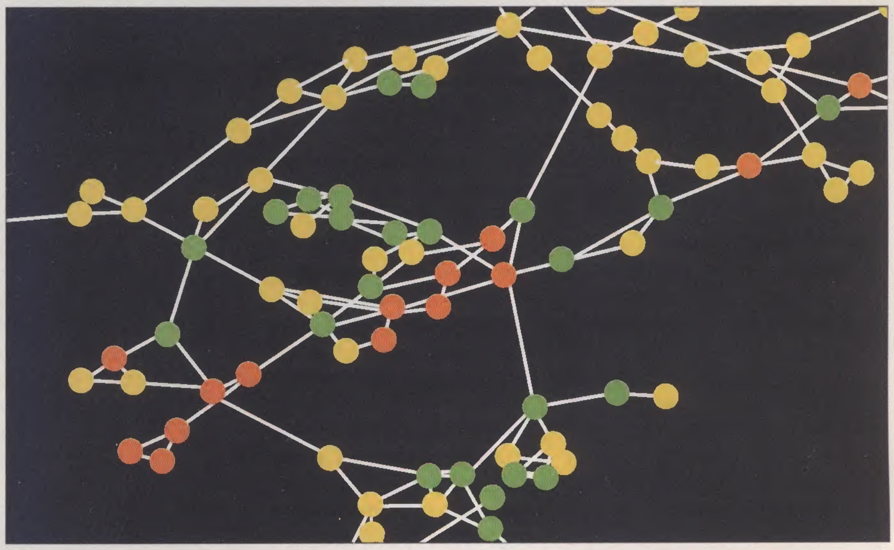
Preview:

MAY 1. By this date, **Wang Laboratories Inc.**, Lowell, Mass., plans to eliminate more than one-third of its remaining workforce, a cut of 3300 jobs—most from manufacturing and corporate staffs. The cut is part of Wang's plan to reorganize as a software and services company so it can emerge from Chapter 11 bankruptcy protection, which it filed last August.

COORDINATOR: Sally Cahur

MAY 1993 Volume 30 Number 5

IEEE SPECTRUM



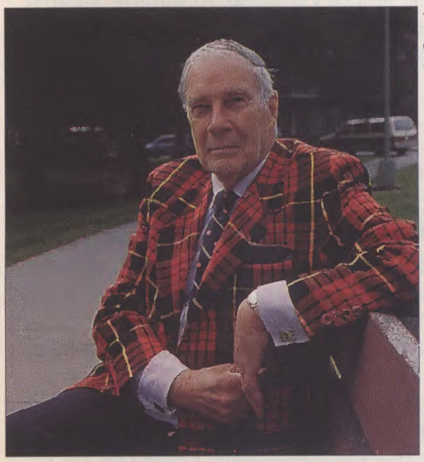
IBM Corp.

Silicon Graphics Inc.

ADVANCED TECHNOLOGY

Brown University

PROFILE



Jon Brenneis

Cover: The spread of computer viruses is impeded by the localized nature of software exchange and word-of-mouth warnings, as shown in this simulation from IBM Corp.'s Thomas J. Watson Research Center. The lines represent diskette exchanges between computers portrayed as yellow dots if normal, orange if infected, and green if recently cured; neighbors of green dots have been issued warnings. See p. 20.

IEEE SPECTRUM (ISSN 0018-9235) is published monthly by The Institute of Electrical and Electronics Engineers, Inc.

345 East 47th St., New York, NY 10017, U.S.A. Cable address: ITRIPLEE. Telex: 236-411. Fax: 212-705-7453. E-mail: ieeespectrum.

ANNUAL SUBSCRIPTIONS. IEEE Members: $11.00 included in dues. Nonmembers: $31.95. Libraries/institutions: $145.
SINGLE COPIES. Members: $8 first copy. Nonmembers: $16.
MICROFICHE SUBSCRIPTIONS. Members: $16. Nonmembers and libraries: $145.
POSTMASTER: Please send address changes to IEEE Spectrum, c/o Coding Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855. Second Class postage paid at New York, NY, and additional mailing offices. Canadian GST #125634188.
Printed at 8649 Hacks Cross Rd., Olive Branch, MS 38654, U.S.A.

IEEE Spectrum is a member of the Audit Bureau of Circulations, the Magazine Publishers of America, and the Society of National Association Publications.

Staff

PUBLISHER: Allan Wittman

ACTING EDITOR: Alfred Rosenblatt

SENIOR TECHNICAL EDITOR: Gadi Kaplan

SENIOR EDITORS: Trudy E. Bell, Richard Comerford, Tekla S. Perry, Michael J. Riezenman

SENIOR ASSOCIATE EDITORS: John A. Adam, Glenn Zorpette

ASSOCIATE EDITOR: Linda Geppert

HEADQUARTERS: New York City 212-705-7555
BUREAUS: WASHINGTON, D.C., John A. Adam, 202-544-3790; *SAN FRANCISCO,* Tekla S. Perry, 415-282-3608

CORRESPONDENTS: Fred Guterl, Roger Milne (London); Bradford Smith (Paris); John Blau (Düsseldorf); Robert Ingersoll (Bonn); John Mason (Barcelona); Stuart M. Dambrot, Roger Schreffler (Toykyo); Kim Nak-Hieon (Seoul); Chris Brown (Taipei); Peter Gwynne (Hong Kong); Tony Healy (Sydney, Australia); Christopher Trump (Toronto); Axel de Tristan (Rio de Janeiro)

CHIEF COPY EDITOR: Margaret Eastman
COPY EDITOR: Sally Cahur
EDITORIAL RESEARCHER: Alan Gardner

CONTRIBUTING EDITORS: Bernard Cole, Lawrence J. Curran, Karl Esch, Ronald K. Jurgen, John King, Kevin Self, Howard Wolff, Michael F. Wolff

EDITORIAL SUPPORT SERVICES:
Rita Holland (Manager)
EDITORIAL ASSISTANTS: Ramona Foster, Desiree Noel

DESIGN CONSULTANT: Gus Sauter

OPERATIONS DIRECTOR: Fran Zappulla
BUSINESS MANAGER: Robert T. Ross

PRODUCTION AND QUALITY CONTROL:
Carol L. White (Director)

EDITORIAL PRODUCTION:
Marcia Meyers (Manager)
Peter Ruffett (Typographer)
Morris Khan (Technical Graphic Artist)

ASSOCIATE PUBLISHER: William R. Saunders
ADMINISTRATIVE ASSISTANT: Christine Demchak
MAIL LIST SALES: Shelly Newman (Manager)
Lizette Graciani
ADVERTISING PRODUCTION:
Theresa Fitzpatrick (Manager)

MARKETING DIRECTOR: Arthur C. Nigro
PROMOTION MANAGER: Robert D. Moran
RESEARCH MANAGER: Hendrik Prins (Manager)
Carl Leibman (Associate)
MARKETING SERVICES: Eric Sonntag (Administrator)

ADMINISTRATIVE ASSISTANT TO THE PUBLISHER:
Nancy T. Hantman

EDITOR EMERITUS: Donald Christiansen

Editorial Board

Forum

Right, wrong, legal?

Having read "It's the law, but is it ethical?" by Donald Christiansen [September, p. 25], I note that instances of breaching ethical boundaries abound in engineering history. Edwin Armstrong defended his patent for the superheterodyne receiver in the courtroom and lost to RCA Corp. He went from that venue the very next day to the IRE [Institute of Radio Engineers] national convention, where he was hailed and honored for that landmark innovation.

Bell Telephone obtained a patent for an oscillator with two tank circuits. Engineers at Bell Laboratories said frankly among themselves that this patent was only a ploy to free Ma Bell from restrictions on the basic patented circuits and that the equivalent circuits were identical.

Leo Gross
New York City

I have read and re-read "It's the law, but is it ethical?" several times, but I still cannot determine precisely what "it" is. I can only guess that Christiansen's "it" is found in the last sentence of his article: "Ethics are often not clear-cut, but *falsification for economic gain* [emphasis added], however rationalized, is not in the gray area."

The only problem is, even among lawyers, "falsification for economic gain" is not and never has been the law.

Christiansen appears to blame lawyers for most of the ethical problems of the engineering profession (for example, "Unfortunately, many engineers seem to assume the coloration of their environments, and easily adapt to the corporate lawyers' culture . . . .Of course, the lawyers are not totally to blame."), but he fails to note that lawyers in every state, unlike most engineers, are governed by a code of ethics having the force of law. Knowingly assisting in the perpetration of a fraud, falsification of evidence, and suborning perjury, as well as being crimes themselves, are among the things that can bring about severe disciplinary action. This can include being barred from the practice of law for the remainder of one's life.

Moreover, as a patent attorney who has been an IEEE member since the late 1970s and as one who, prior to becoming an attorney, had over 10 years of engineering work experience, I find the potential ramifications of Christiansen's article quite alarming. Engineers should certainly not assume that legal ethics permit "falsification for economic gain," irrespective of what they may read in *IEEE Spectrum*. I do not relish the thought of clients, particularly fellow IEEE members, who make such assumptions about my practice. I know of no colleagues who would like to have such engineers as clients, either, since this type of client may needlessly force an attorney into very unpleasant ethical dilemmas.

Of somewhat less significance, but still troubling, is Christiansen's uncritical acceptance of the assertion that the United States leads all nations in lawyers per "square centimeter," a variation of a bromide often repeated by those who stand to gain economically or politically by such acceptance. Typically, only licensed attorneys (or, for some countries, only one of several classes of licensed attorneys) are counted in international comparative studies.

Counting attorneys this way is as misleading as using the number of professional engineering licenses as an estimate of the total number of engineers in the United States, since most countries license only a fraction (sometimes *zero*) of those who provide legal advice or services comparable to U.S. attorneys.

A more realistic comparison based on number of law degrees reveals that the United States actually ranks 35th in the world in number of law providers per 10 000 population—behind both Japan and Germany. The [territory] with the most lawyers per square centimeter is Vatican City, where more than one-third of all the "official" residents are lawyers (see "The Mythical Kingdom of Lawyers," *ABA Journal*, September 1992).

Alan L. Cassel
New Providence, N.J.

Energy in, energy out

I found the article "Kilowatts on order" [February, pp. 32–37] interesting and informative. However, it seemed to gloss over several crucial aspects of PWM [pulse-width modulation] amplifier operation.

For example, the sidebar on p. 34 states, "During the on period, the entire DC supply voltage . . . is applied to the load." Of course, this cannot be true, or else the output voltage would equal the supply voltage. In order for the output voltage to differ from the supply voltage, they must be separated by a component that generates a voltage drop. In fact, the supply voltage is applied to the output filter, and the inductor generates the necessary voltage drop.

On this analysis, we see that a PWM amplifier must hold off from the load whatever voltage it does not deliver, just as a linear amplifier must. The reason that the PWM amplifier is more efficient is that it does this with a component that stores energy (an inductor) rather than a component that dissipates energy (a transistor). The stored energy is later delivered to the load, or returned to the supply rails.

Of course, all this is implicit in the statement, "Output filtering attenuates harmonics of the switching frequency . . . ." However, those accustomed to thinking of filters as signal-conditioning devices may not appreciate the full significance of the output filter in managing the flow of energy and current between the supply and the load.

Steven McDougall
Littleton, Mass.

More on multimedia

I was dismayed by the incomplete discussion of interactive media in the March issue [pp. 22–39]. The authors did not report on one of the most popular multimedia personal computer platforms in the world—the Commodore Amiga, which offers a wide range of powerful tools for creative and effective multimedia production.

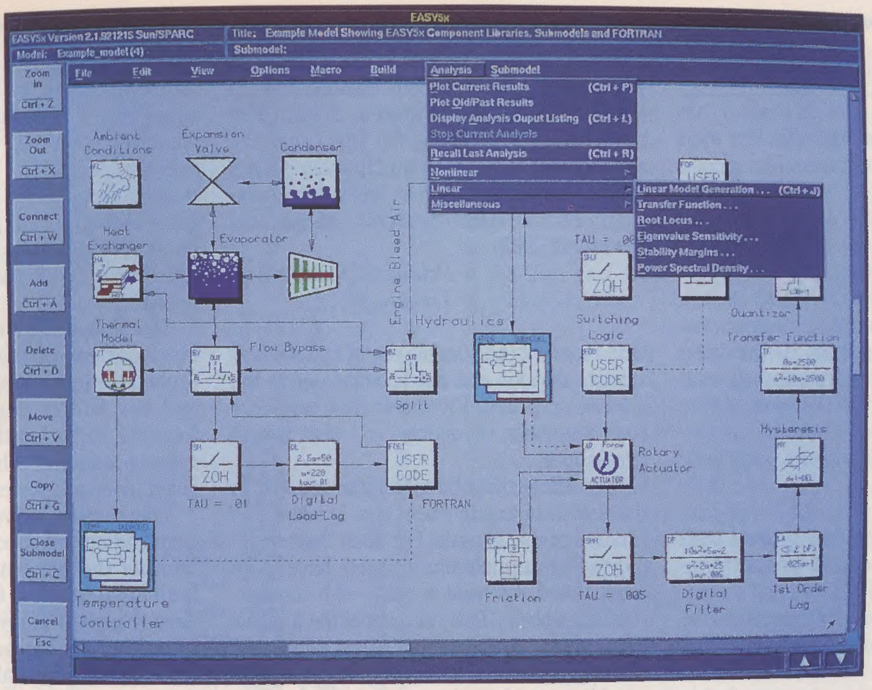
At its introduction in 1985, the Amiga offered a multitasking operating system, broadcast-quality video graphics capability, and four-channel stereo sound. At the time, the Macintosh and PC compatibles offered only single-tasking operating systems with monochrome graphics and sound systems capable of little more than beeps and clicks. Today, Commodore offers a wide variety of Amiga computers from very inexpensive home machines to computers of almost workstation power. John Adam suggests that a full-featured multimedia PC would cost around US $2700. A similarly featured Amiga system would cost less and quite probably outperform such a system.

James E. Cook
Aloha, Ore.

Fax: drums in the dark

After seeing the article "Facsimile's false starts" [February, p. 44–49], I thought readers might be interested in yet another false start—this one by the well-known scientist V. K. Zworykin.

It happened about 1928 when Zworykin was working in the Research Laboratories of Westinghouse in East Pittsburgh, Pa. He



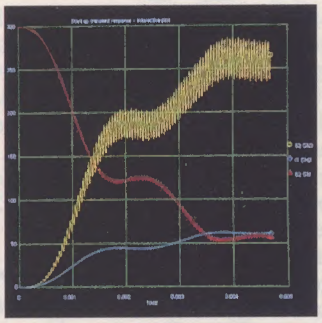
Modeling and analysis completed with a Motif®-based X Window™ interface.

Does it go bump in the night?

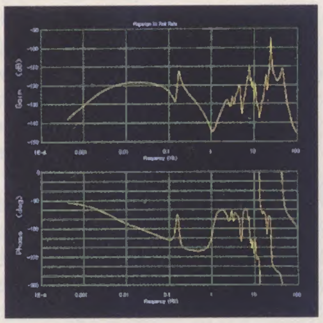
Is it stable? Can you control it? And, what happens when you turn it on?

If you design electrical, hydromechanical, chemical, and/or digital control systems, these are the kinds of questions you probably have.

You want to know how the system behaves, and if it can be controlled. But you can't afford to spend a lot of time and money in the process.



Non-linear simulation results viewed interactively or off-line.



Frequency-response data displayed in Bode, Nichols, or Nyquist formats.

With EASY5x®, you'll get the answers you want. And you'll get them cost-effectively.

Proven software.

Developed, tested, and refined at Boeing, EASY5x has been used to model, simulate, and analyze complex and highly non-linear systems. Especially those containing microprocessor-based controllers.

And today, engineers worldwide are using EASY5x in a variety of industries. For example, EASY5x helps build the cars you drive, the airplanes you fly, and the power plants you depend on.

Unparalleled system modeling.

With EASY5x, modeling difficult system dynamics can be a routine exercise.

That's because EASY5x comes with hundreds of modeling blocks. Including discontinuous elements like friction, hysteresis, and hard limits.

Our libraries are also full of physical elements such as hydraulics, heat exchangers, and freon components.

You can even create your own modeling blocks and share them freely. EASY5x helps by maintaining tight configuration control for you.

Efficient analyses.

EASY5x provides simulation performance up to 100 times faster than other software on the market.

Even our control system analysis tools will save you time, particularly when you analyze multi-rate sampled-data systems.

And if you need world-class solutions to real-time simulation problems, EASY5x software now interfaces with hardware supplied by Applied Dynamics International.

Call for a free trial.

EASY5x is sophisticated enough to be simple to use. It's supported by a highly trained technical staff. And the software is mature enough to provide answers to really tough dynamics problems accurately and quickly.

You can get started with EASY5x on your Sun, Hewlett-Packard, Digital, Silicon Graphics, or IBM RS6000™ UNIX® workstation for $8,900. (U.S. and Canadian universities may join our University Program at no cost.)

All things considered, EASY5x is the best value on the market. And we'd like to prove it to you.

Call for a free, 30-day trial. Phone 1-800-426-1443 or FAX 206-865-2966. Or write to Boeing, P.O. Box 24346, M/S 7L-46, Seattle, WA 98124-0346, USA.

Circle No. 9

BOEING

Forum

wrapped the page to be sent on a drum that was about the size of the wax cylinders used on those old dictating machines, Dictaphone or Ediphone. A photoelectric head scanned the rotating drum as the drum was being moved along the axis of the cylinder.

On the receiving set, a sheet of photographic printing paper was wrapped about a similar drum. A modulated neon light was focused on the receiving drum. As the drum rotated while being moved transversely with the dictaphone lead screw, the picture was painted on the sensitized paper. Of course, both drums rotated in darkness, especially the receiving drum.

My part in this venture was developing the special drive systems that rotated both sending and receiving drums at the same speed. Zworykin did not want to use ac synchronous motors because he wanted to be able to use his system independently of commercial ac power.

Around 1928, Zworykin described this system to the Pittsburgh AIEE [American Institute of Electrical Engineers] Section. At this meeting, I assisted him by transmitting a portrait photograph across the stage with his machines.

Not long afterward, Zworykin left Westinghouse to go to RCA. So far as I know, no real attempt was ever made to exploit this system commercially.

Cyril J. Veinott
Sarasota, Fla.

Roll on, electric vehicles

One important technology that was not covered in your special report, "Electric vehicles: architecting the system" [November, pp. 18–24, 93–101], was fuel cells. In addition to high kilowatt-per-pound ratio, simplicity of operation, zero emission reaction (the byproduct is water), and long life, fuel cells provide a key advantage over dry cell batteries in that they are not recharged in the conventional manner.

When the fuel cell in an electric vehicle is depleted, you do not plug it into the nearest outlet and wait for a few hours as you would with a conventional battery. Instead, you drive up to the nearest hydrogen "service station" and pump more compressed hydrogen fuel into your on-board storage tank, an operation measured in minutes and analogous to our current system implementation. Our existing infrastructure of pipelines and service stations could be modified to transport and store hydrogen fuel so that the driving habits of the future would be very similar to the driving habits of today.

There are problems associated with this approach, not the least of which is safe and reliable storage of hydrogen fuel; however, fuel cells offer some intriguing features for which they deserve serious consideration in these initial stages of system design. For more information about the latest fuel cell applications, refer to John Hirschenhofer's article, "Latest program in fuel cell technology," *IEEE AES Systems Magazine*, November 1992.

Reinhardt Schornstaedt
Trenton, N.J.

One aspect of the possible use of flywheels as storage devices was not brought out in the sidebar on p. 100. Flywheels that can store large amounts of energy are also potent gyroscopes.

This effect must be taken into account in the design of any flywheel that is subject to rotation of its spin axis. For such "batteries," they will at a minimum probably have to be constructed and used in pairs, with counter-rotating wheels. This can cancel the angular momentum about one axis, but additional wheel pairs at 90 degrees may also be needed. All is not lost, however, because with proper orientation the precessional forces can be used to produce a vehicle that is more stable on turns and also to increase the forces on specific wheels.

About 1970, I studied possible flywheel applications at Norden Division of United Technologies. They could have uses in providing temporary power (such as portable X-ray machines), emergency services (such as hoists on helicopters), and even electric utilities energy storage. It is possible to store as much energy (per mass) as some explosives. This fact will undoubtedly result in government regulations.

I concluded that this could limit the flywheels in cars to the point that they were not economical competitors of chemical storage. In the 1970s there was little cause to expect a favorable government environment for flywheels in cars. It may be better now or in the future.

Frank S. Preston
Williamsburg, Va.

Implications of regulations

In arguing for regulation of encryption ["Wiretapping and cryptography," March, pp. 16–17], Dorothy E. Denning writes that while criminals could surely build illegal encryption devices, "... the amount of work required to acquire and use them may deter their use." It seems to me that while such deterrence is effective against the small-time crook, it rewards organized criminals with larger R&D budgets. Is this desirable?

John W. Dooley
Millersville, Pa.

I must take exception to Denning's view that a contract exists that limits our rights to privacy. I will agree that U.S. laws reflect a limitation on our rights to privacy, but I do not agree that it constitutes a "social contract," whatever that is. Contracts exist only between people, not social institutions. And these contracts constitute a specific agreement by both or all parties to the contract. Most laws get passed without the specific agreement of all parties (that is, the governed).

The closest thing to a social contract that most citizens of the United States would probably agree to is the U.S. Constitution and the Bill of Rights. This country's founders had a healthy respect for the corruption ensuing when governments are given too much power over their citizens.

The right to privacy guaranteed in the Constitution was specifically directed toward limiting the government's intrusion into individual affairs. Our government has already passed too many laws violating our constitutional rights in favor of granting some groups special rights. To claim this constitutes a social contract is misleading. All it means is that our constitutional safeguards are being eroded.

Leo K. Anderson Jr.
Colorado Springs, Colo.

Credit where it's due

The April issue cover story on how engineers see themselves, their jobs, and the rapidly evolving environment in which they work, was based on a *Spectrum* subscriber direct-mail survey conducted by Erdos & Morgan/MPG, an international research organization, and jointly sponsored by *Spectrum* and the IEEE United States Activities Board (USAB).

Corrections

The following names were inadvertently omitted from the April 1993 masthead: Senior Technical Editor: Gadi Kaplan; Correspondents: Fred Guterl, Roger Milne, Bradford Smith, John Blau, Robert Ingersoll, John Mason, Stuart M. Dambrot, Roger Schreffler, Kim Nak-Hieon, Chris Brown, Peter Gwynne, Tony Healy, Christopher Trump, and Axel de Tristan.

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*, on the policies and operations of the IEEE, and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate. Contact: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017-2394, U.S.A.; fax, 212-705-7453. The Compmail address is ieeespectrum. The computer bulletin board number is 212-705-7308 and the password is SPECTRUM; for more information, call 212-705-7305 and ask for the Author's Guide.

oks

ptional memorizers
mmers. Gates had
at the time as a sub-
ıs at Harvard when I

ssipy outsider's view
'th company. It is a
cal account. I found
querque eras espe-
vealing.
er, Paul Allen, were
eneurs that venture
ı. Nor would such a
company, anyway.
lists probably would
re than helped it.
siness tycoon with a
f technology, Gates
and energy to make
capable of making a
pping out of Harvard,
p.
for Microsoft came
ok its biggest risks,
because of his mas-
ogy and the business
ft. A manager who
nderstanding of the
e manager, in other
aken the risk of sell-
perating system," or
t of Windows when
ompany in the world
promote another of
rusting to a young-
sive, brilliant one—
e Japanese market.
rd-driving leader, he
t. But such a charac-
I think. He has writ-
software personally.
every line of code
llion-dollar enter-
true of chief execu-
nies earning a thou-
revenues. Further-
s time reading code.
a user of his prod-
s on the diskettes as
n understanding and
hat understanding.
hat frightens many

lot of time walking
Wal-Mart stores he
ow they could be
understood cars and
es. He also under-
s workers too little,
o afford his automo-
ew how to sell IBM
raged this ability in

creating a start-up company financed by advance sales. John D. Rockefeller parlayed profits from a grain commission house into the oil business. He realized the need for more centralized control over the complete life cycle of oil, from exploration to production to distribution.

Gates has combined Walton's hands-on approach with Ford's understanding of the business, Perot's salesmanship, and Rockefeller's need for control. A modest family tie to the president of IBM may not have been irrelevant in the beginning, either.

What did I learn from this book? Many details about Microsoft's early years and a few about the events of the last seven. I learned a lot more about chairman Bill and the culture of Microsoft. Given Gates's current and future influence on microcomputer software (let's face it: most of his professional career is still ahead of him), nobody in the industry can operate effectively without a solid understanding of Microsoft and Gates. This book would be an excellent start.

While reading it, I began to wonder, how can Microsoft continue growing and prospering, given its culture of "personal hard drive"? Could that feature become yet another bug?

Entrepreneurs will work for years to get the big payoff. But the employees of a billion-dollar company seem to have a really difficult time maintaining that start-up tempo. Microsoft personnel attitudes seem unsustainable. Even 2200 millionaires operating in positions of influence may not be enough. But then, Andrew Carnegie, Henry Ford, and John D. Rockefeller had to face exactly the same challenge.

Somehow, one senses that Gates is up to the challenge. After all, to paraphrase a well-known slogan, he made his money the old-fashioned way. He earned it.

Tom Love is president of OrgWare Inc., a Roxbury, Conn., management consulting and training firm specializing in object-oriented software. He is the author of Object Lessons: Lessons Learned in Commercial Object-Oriented Development Projects, *to be released this month by SIGS Books in New York.*

At the door of life

Lawrence Hunter

Innovations in computer science have often been driven by the offbeat ideas of fringe visionaries like Marvin Minsky, John von Neumann, and Alan Turing. Today, a colorful new group of researchers claims to have found revolutionary approaches to computing, built on analogy to the structure and

wrapped the page to be sent on a drum that was about the size of the wax cylinders used on those old dictating machines, Dictaphone or Ediphone. A photoelectric head scanned the rotating drum as the drum was being moved along the axis of the cylinder.

On the receiving set, a sheet of photographic printing paper was wrapped about a similar drum. A modulated neon light was focused on the receiving drum. As the drum rotated while being moved transversely with the dictaphone lead screw, the picture was painted on the sensitized paper. Of course, both drums rotated in darkness, especially the receiving drum.

My part in this venture was developing the special drive systems that rotated both sending and receiving drums at the same speed. Zworykin did not want to use ac synchronous motors because he wanted to be able to use his system independently of commercial ac power.

Around 1928, Zworykin described this system to the Pittsburgh AIEE [American Institute of Electrical Engineers] Section. At this meeting, I assisted him by transmitting a portrait photograph across the stage with his machines.

Not long afterward, Zworykin left Westinghouse to go to RCA. So far as I know, no real attempt was ever made to exploit this system commercially.

Cyril J. Veinott
Sarasota, Fla.

Roll on, electric vehicles

One important technology that was not covered in your special report, "Electric vehicles: architecting the system" [November, pp. 18–24, 93–101], was fuel cells. In addition to high kilowatt-per-pound ratio, simplicity of operation, zero emission reaction (the byproduct is water), and long life, fuel cells provide a key advantage over dry cell batteries in that they are not recharged in the conventional manner.

When the fuel cell in an electric vehicle is depleted, you do not plug it into the nearest outlet and wait for a few hours as you would with a conventional battery. Instead, you drive up to the nearest hydrogen "service station" and pump more compressed hydrogen fuel into your on-board storage tank, an operation measured in minutes and analogous to our current system implementation. Our existing infrastructure of pipelines and service stations could be modified to transport and store hydrogen fuel so that the driving habits of the future would be very similar to the driving habits of today.

There are problems associated with this approach, not the least of which is safe and reliable storage of hydrogen fuel; however,

fuel cells offer som
which they deserve
these initial stages
more information a
applications, refer t
article, "Latest prog
ogy," *IEEE AES*
November 1992.

One aspect of the pc
storage devices was
sidebar on p. 100. F
large amounts of
gyroscopes.

This effect must
the design of any fl
rotation of its spin a
they will at a minim
constructed and use
rotating wheels. Th
momentum about
wheel pairs at 90 de
ed. All is not lost,
proper orientation
can be used to pr
more stable on tur
the forces on specifi

About 1970, I st
applications at Nor
Technologies. They
viding temporary p
X-ray machines), en
as hoists on helicop
utilities energy st
store as much ene
explosives. This fac
in government regu

I concluded that
wheels in cars to t
not economical cc
storage. In the 1970
to expect a favorab
ment for flywheels
now or in the future

Implications

In arguing for re
["Wiretapping and c
16–17], Dorothy E. I
criminals could sure
devices, ". . . the am
acquire and use ther
seems to me that v
effective against t
rewards organized
R&D budgets. Is thi

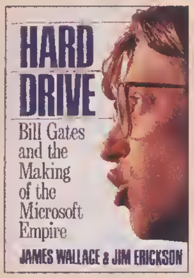
I must take exceptic
a contract exists tha

Books

He's a tycoon, not a tyrant

Tom Love

Hard Drive: Bill Gates and the Making of Microsoft.
Wallace, James, and Erickson, Jim, John Wiley & Sons, New York, 1992, 426 pp., US $22.95.



I lived across the street from Microsoft's current office complex when it was a forest. I shared an office with the systems guy behind CP/M. And I have been a student and participant in the software industry for 20 years. So I wanted to read this book. In fact, I read it in two sittings.

Fortunes are made when fundamental industries are created or radically improved. Some examples: Andrew Carnegie (steel), John D. Rockefeller (oil), Henry Ford (automobiles), J. P. Morgan (investment banking), Eleuthère Irénée du Pont (chemicals), Leland Stanford (railroads), Sam Walton (discount stores), H. Ross Perot (system integration), and, last but not least, William Gates (microcomputer software).

Notice that computers are not on the list. Major fortunes are made when personally financed companies are created in new, basic industries. Leland Stanford was unique in that he managed to get public financing for a large expansion of the existing railroads industry, while also retaining a major personal stake in what was created.

Bill Gates got on this list at a much earlier age than anyone else in history. But Gates shares the determination, the dedication, and the ruthlessness of everyone else listed. These, much more than proper education and social graces, are the attributes of fortune makers.

Gates is also distinctive in raw intellect, which is perhaps fitting for someone who built his empire in an information industry. He was a whiz in school—when he applied himself. He consumes information at a prodigious rate and retains far more than most of his competitors. He also keeps his information engine running longer each week than anyone else in the industry.

Hard Drive tells the fascinating story of the early days of Microsoft with surprising accuracy. Since the authors are reporters, not participants in the story itself, I expected far more errors. I found just two minor ones, only because I was at the University of Washington in the early 1970s, studying the characteristics of exceptional memorizers and computer programmers. Gates had been mentioned to me at the time as a subject for study, but he was at Harvard when I needed him.

The book is not a gossipy outsider's view of a phenomenal growth company. It is a well-researched historical account. I found the Lakeside and Albuquerque eras especially interesting and revealing.

Gates and his partner, Paul Allen, were not the type of entrepreneurs that venture capitalists like to bet on. Nor would such a bet have helped the company, anyway. Indeed, venture capitalists probably would have hurt Microsoft more than helped it.

The epitome of a business tycoon with a deep understanding of technology, Gates also has the dedication and energy to make big things happen. He is capable of making a tough decision, like dropping out of Harvard, or challenging IBM Corp.

The largest victories for Microsoft came when the company took its biggest risks, which Gates could do because of his mastery of both the technology and the business objectives of Microsoft. A manager who lacked a fundamental understanding of the business (a content-free manager, in other words) would not have taken the risk of selling IBM a "purchased operating system," or continuing development of Windows when the largest computer company in the world wanted to endorse and promote another of his products, or of entrusting to a youngster—even an aggressive, brilliant one—the job of opening up the Japanese market.

Because Gates is a hard-driving leader, he may often seem a tyrant. But such a characterization is inaccurate, I think. He has written a lot of computer software personally. He knows how to read every line of code written in his multibillion-dollar enterprise—which is rarely true of chief executives of software companies earning a thousandth of Microsoft's revenues. Furthermore, Gates still spends time reading code. He is not content to be a user of his products; he cares what goes on the diskettes as well. Power comes from understanding and an ability to act on that understanding. Gates has both, and that frightens many competitors.

Sam Walton spent a lot of time walking around the thousands of Wal-Mart stores he owned to find out how they could be improved. Henry Ford understood cars and especially assembly lines. He also understood that if he paid his workers too little, they would not be able to afford his automobiles. H. Ross Perot knew how to sell IBM computers and he leveraged this ability in creating a start-up company financed by advance sales. John D. Rockefeller parlayed profits from a grain commission house into the oil business. He realized the need for more centralized control over the complete life cycle of oil, from exploration to production to distribution.

Gates has combined Walton's hands-on approach with Ford's understanding of the business, Perot's salesmanship, and Rockefeller's need for control. A modest family tie to the president of IBM may not have been irrelevant in the beginning, either.

What did I learn from this book? Many details about Microsoft's early years and a few about the events of the last seven. I learned a lot more about chairman Bill and the culture of Microsoft. Given Gates's current and future influence on microcomputer software (let's face it: most of his professional career is still ahead of him), nobody in the industry can operate effectively without a solid understanding of Microsoft and Gates. This book would be an excellent start.

While reading it, I began to wonder, how can Microsoft continue growing and prospering, given its culture of "personal hard drive"? Could that feature become yet another bug?

Entrepreneurs will work for years to get the big payoff. But the employees of a billion-dollar company seem to have a really difficult time maintaining that start-up tempo. Microsoft personnel attitudes seem unsustainable. Even 2200 millionaires operating in positions of influence may not be enough. But then, Andrew Carnegie, Henry Ford, and John D. Rockefeller had to face exactly the same challenge.

Somehow, one senses that Gates is up to the challenge. After all, to paraphrase a well-known slogan, he made his money the old-fashioned way. He earned it.

Tom Love is president of OrgWare Inc., a Roxbury, Conn., management consulting and training firm specializing in object-oriented software. He is the author of Object Lessons: Lessons Learned in Commercial Object-Oriented Development Projects, *to be released this month by SIGS Books in New York.*

At the door of life

Lawrence Hunter

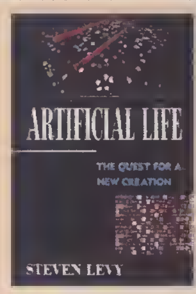
Innovations in computer science have often been driven by the offbeat ideas of fringe visionaries like Marvin Minsky, John von Neumann, and Alan Turing. Today, a colorful new group of researchers claims to have found revolutionary approaches to computing, built on analogy to the structure and

Books

function of living systems. The work, called artificial life by its creators, seems ready to emerge from a long history of furtive, garage science into the light of legitimate academic pursuit, if not yet into the heat of industrial application.

The people and the technology are ably chronicled in this book. Levy's attraction to the combination of radical thought and high technology (his first book was *Hackers*, about the computer *demimonde*) and his

Artificial Life: The Quest for a New Creation.
Levy, Steven, Pantheon, New York, 1992, 390 pp., $25.



fundamentally humanist but technically careful approach has produced a masterful introduction to artificial life, one that captures many of its most striking aspects, both human and technological.

Artificial life encompasses a variety of research directions, including self-replicating cellular automata, environments where programs evolve through competition for memory locations and central processor cycles, pattern grammars that generate structures with startling likenesses to the intricate branching and flowering of plants, and even miniature autonomous robots. All these ideas have met with resistance from the traditional computer science community as impractical, insignificant, or bound to fail. Bit by bit, however, this resistance is being overcome.

For more than 25 years, in the face of indifference or even hostility from his fellow computer scientists, John Holland of the University of Michigan has been pursuing his vision of how programs can be evolved, rather than designed. Over the last few years the approach, termed genetic algorithms, has been recognized as an effective method for optimizing many-parameter systems and other computationally difficult tasks. A large group at the U.S. Naval Research Laboratory applies the algorithms to problems in tracking targets (and evading pursuers), and industrial applications in manufacturing and control of complex systems are starting to come on-line.

Early practical applications like these have opened at least a few eyes. Before the first artificial life conference in 1989, one scientist asked a Nobel Prize–winning colleague if he should attend, and was told: "This is the sort of conference you might go to, but never tell a soul you were there."

It has not taken long for that attitude to change. Due in large part to the efforts of Chris Langton in organizing conferences and publishing books, artificial-life research is receiving more positive recognition; of late, articles have appeared in top journals and newspapers. The media attention is due primarily to the interesting ideas and the eye-catching demonstrations, but Levy's book has also been influential.

Artificial-life work is gaining scientific respectability, too. The National Institutes of Health, Bethesda, Md., has bestowed a grant on Gerald Joyce, a researcher at the Scripps Institute in San Diego, Calif., to use a methodological cross between artificial life and biochemistry to evolve ribonucleic acid (RNA) enzymes that attack the acquired immunodeficiency syndrome (AIDS) virus.

Joyce is a champion of the serious scientific application of this work. In his role as an advisor to the National Aeronautics and Space Administration (NASA), he has made a point of legitimizing the funding the agency might devote to that area in the future. He felt that researchers who dared to label their work as artificial life should not have to subsume it under fields less liable to cheap gibes. "I made that argument with NASA scientists, and they've bought it," he said. "That's now an explicit part of the goals of the program—to make life. Whatever the substrate may be."

Perhaps more compelling than a few successful military or industrial applications are the fundamental questions of life itself. Biologists are often suspicious of theoretical models that cannot be tested in the laboratory. Nevertheless, some of the artificial-life models are so lifelike that the biological community has taken notice.

The claims of the artificial-life community go even further. By writing programs that reproduce themselves, evolve, and adapt to their environments in ways their creators never envisioned, artificial-life researchers claim their *in silico* experiments are helping define the parameters of life in general, not just the kind found here on earth.

Rod Brooks, director of the Massachusetts Institute of Technology's mobile robot (Mobot) laboratory in Cambridge, has been producing machines that are, in one of the lab's favorite slogans, small, fast, and out of control. The robots are independent wanderers that, to a surprising degree, are capable of taking care of themselves in the real world (or around the real world of the computer science building, at least).

One of Brook's researchers, Paul Viola, argues that the classic cybernetic work of Grey Walter surpassed bacterial intelligence, and his robot, Atilla, falls only slightly short of insect-level intelligence.

Viola further claims that he will be able to simulate life at the canine level within a decade. He has even bet a friend a case of fine cognac that he would build a robot so dog-like in its behavior that, for all practical purposes, it really would be a dog. The test is that Viola will bring it home and show it to his friend's (yet unborn) children. If they love it, Viola will win the bet.

The creation of life by humans (other than in the traditional way) has been the stuff of legend throughout history. The stories are almost all cautionary tales of hubris and disaster: the Golem and Frankenstein, for example. Levy and the artificial-life researchers do not shy away from the inherently moral question of whether artificial life itself should be encouraged. One researcher is frighteningly honest about the problem: "If you ask me really honestly, 'Steen, why are you doing this?' I can't answer you," he says. "I feel in some way that I am committing a sin by the things I am doing."

One vivid example of the power and the risk involved in artificial-life research is the computer virus. Although biologists argue whether their viruses are alive or not, they recognize that because the viruses are parasites on successful hosts, and because they evolve to find new ways to evade their hosts' immune systems and successfully reproduce, we shall never be rid of them.

Computer viruses, built by analogy with biological ones, are arguably the first artificial-life form to survive outside the laboratory. For now, they may be an annoyance no worse than the common cold, but the warning about artificial life's potential ramifications is clear.

Levy's book does an excellent job with a difficult task. He clearly explains the technical details of the research without overwhelming the general reader, and gets almost everything right. He captures the driving personalities of the researchers in the field, exploring the relationships between people and science that are too often ignored. And while he is clearly captivated by the excitement of the work, he carefully explores the potential for harm and the difficult moral questions that arise.

Whether your interests are in the technical details of a new approach to computation, the human story of a scientific revolution, or the impending satisfaction of the age-old craving to create life in the laboratory, you should read this book.

Lawrence Hunter is director of the Machine Learning Project at the National Library of Medicine in Bethesda, Md. His current research involves the goal-driven selection, combination, and application of multiple machine-learning technologies to problems in biology and medicine. He is also interested in the origins and implications of the desire for knowledge, the evolution of cognitive abilities, and the social implications of technical advances in biology and computer science. His book Artificial Intelligence and Molecular Biology *was published last fall by MIT/Press.*

COORDINATOR: Glenn Zorpette

Calendar

Meetings, Conferences, and Conventions

MAY

International Workshop on VLSI Process and Device Modeling—VPAD (ED); May 14–15; New Public Hall, Nara, Japan; Masao Fukuma, Microelectronics Research Laboratories, NEC Corp., 1120 Shimokuzawa, Sagamihara, Kanagawa 229, Japan; (81+42) 771 0886.

20th International Symposium on Computer Architecture (C); May 16–19; Sheraton Harbour Island Hotel, San Diego, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Wescanex '93—Conference on Communications, Computers and Power in the Modern Environment (Region 7 et al.); May 17–18; University of Saskatchewan, Saskatoon; Ron Fleming, Department of Electrical Engineering, University of Saskatchewan, Saskatoon, Sask. S7N OWO, Canada; 306-966-5299 or 5379; fax, 306-966-8710.

VLSI Technology Symposium (ED); May 17–19; Kyoto Grand Hotel, Kyoto, Japan; James T. Clemens, AT&T Bell Laboratories, 600 Mountain Ave., Murray Hill, N.J. 07974; 908-582-2800.

Particle Accelerator Conference (NPS); May 17–20; Omni Shoreham, Washington, D.C.; Christoph W. Leemann, CEBAF, 12000 Jefferson Ave., Newport News, Va. 23606; 804-249-7554.

Eighth Annual Conference on Structure in Complexity Theory (C); May 17–21; Sheraton Harbor Island Hotel, San Diego, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

15th International Conference on Software Engineering (C, ACM); May 17–21; Stouffer Harbor Place Hotel, Baltimore, Md.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 201-728-0884.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 80055; 908-562-3878; submit conferences for listing to: Ramona Foster, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017; 212-705-7305.

For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

Calendar

(Continued from p. 14)

Instrumentation and Measurement Technology Conference (IM); May 18–20; Hyatt Regency Hotel, Irvine, Calif.; Robert Myers, 3685 Motor Ave., Suite 240, Los Angeles, Calif. 90034; 310-287-1463; fax, 310-287-1851.

International Symposium on Power Semiconductor Devices and ICs (ED); May 18–20; Hyatt Regency Monterey, Monterey, Calif.; M. Ayman Shibib, AT&T Bell Laboratories, Box 13566, Reading, Pa. 19612-3566; 215-939-6576.

University/Government/Industry Microelectronics Symposium (ED); May 18–20; North Carolina State University, Raleigh; Jeffrey A. Coriale, North Carolina State University, Box 7920, Centennial Campus, Raleigh, N.C. 27695; 919-515-5053; fax, 919-515-5055.

Vehicular Technology Conference—VTC (VT, North Jersey Section); May 18–20; Meadowlands Hilton Hotel, Secaucus, N.J.; Melvin Lewis, Loral Electronic System Ridge Hill, M/S-29, Yonkers, N.Y. 10710; 914-968-2500; fax, 914-964-2891.

Symposium on Solid Modeling and Applications (C); May 19–21; Ramada Renaissance, Montreal; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave. N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Symposium on VLSI Circuits (SSC); May 19–21; Kyoto Grand Hotel, Kyoto, Japan; Dru Montgomery, Courtesy Associates, 655 15th St., N.W., #300, Washington, D.C. 20005; 202-347-5900; fax, 202-347-6109.

Pacific Rim Conference on Communications Computers and Signal Processing (Region 7 et al.); May 20–21; Victoria Conference Centre, Victoria, B.C., Canada; Russ Williams, Conference Services, University of Victoria, Box 3030, Victoria, BC V8W 3N6, Canada; 604-721-8 451; fax, 604-721-8774.

International Software Metrics Symposium (C); May 21–22; Stouffer Hotel, Baltimore, Md.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Conference on Communications (COM); May 23–26; CICG Centre International de Conférences de Genève, Geneva, Switzerland ; Peter Leuthold, Institut für Kommunikationstechnik, ETH-Zentrum, CH-8092 Zurich, Switzerland; (41+1) 256 2788; fax, (41+1) 262 0943.

Workshop on Interconnections Within High Speed Digital Systems (E, COM, LEO); May 23–26; Eldorado Hotel, Santa Fe, N.M.; Cathy Goldsmith, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3894; fax, 908-562-1571.

35th Cement Industry Technical Conference (IA); May 23–27; Royal York Hotel, Toronto; John MacRitchie, Leeds & Northrup Canada, 134 4 Fewster Dr., Mississauga, Ont., Canada L4W 1A4; 416-238-6850.

Third Annual Dual-Use Technologies and Applications Conference (MV Section); May 24–27; Suny Institute of Technology, Utica/ Rome, N .Y.; John Salerno, c/o College Relations Office, Suny Institute of Technology, Box 3050,

(Continued on p. 14FE)

Calendar

(Continued from p. 14BE)

Utica/Rome, N.Y. 13504-3050; 315-792-7114; fax, 315-792-7222.

23rd International Symposium on Multiple Valued Logic (C); May 24–27; Hyatt Regency Hotel, Sacramento, Calif.; K.W. Current, ECE Department, University of California, Davis, Calif. 95616; 916-752-0583; fax, 916-752-8428.

National Aerospace and Electronics Conference (AES, Dayton Section); May 24–28; Dayton Convention Center, Dayton, Ohio; Sue Murphy, ASC/ENES, Wright-Patterson Air Force Base, Ohio 45433-6503; 513-255-6281.

Regional Conference on Aerospace Control Systems (CS); May 25–27; Rockwell Science Center, Thousand Oaks, Calif.; Ching-Fang Lin, American GNC Corp., 9131 Mason Ave., Chatsworth, Calif. 91311; 818-407-0092.

International Conference on Distributed Computing Systems—ICDCS '93 (C); May 25–28; Pittsburgh Hilton and Towers, Pittsburgh; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013 .

Canadian Workshop on Information Theory (IT, Region 7); May 30–June 2; Le Riviera Conference Centre, Rockland, Ont.; T. Aaron Gulliver, Department of Systems and Computer Engineering, Carleton University, Ottawa, Ont., Canada K1S 5B6; 613-788-5734; fax, 613-788-5727.

JUNE

43rd Electronic Components and Technology Conference—ECTC '93 (CHMT); June 1–3; Buena Vista Palace Hotel, Orlando, Fla.; James A. Bruorton, Kemet Electronics, Box 5928, Greenville, S.C. 29606; 803-963-6621

International Symposium on Industrial Electronics—ISIE '93 (IA et al.); June–3; Hotel Agro, Budapest, Hungary; Okyay Kaynak, Bogazici University, Bebek, 80815 Istanbul, Turkey; (90+1) 265 9909; fax, (90+1) 257 5030.

International Symposium on Electron, Ion and Photon Beams (ED); June 1–4; Sheraton Harbor Island, San Diego, Calif.; Fritz J. Hohn, IBM Research Division, Thomas J. Watson Research Center, Box 218, Yorktown Heights, N.Y. 10598; 914-945-1608; fax, 914-945-4121.

Get 3 Books for only $9.95

when you join the

Electronics Engineers' Book Club®

YES! Rush me the following titles, billing me just $9.95 (plus shipping/handling & sales tax). Enroll me as a member of the **Electronics Engineers' Book Club** according to the terms outlined in this ad. If not satisfied, I may return the books within 10 days without obligation and my membership will be cancelled. I agree to purchase just 3 more selections at regular Club prices during the next 2 years and may resign anytime thereafter.

Code #'s of my books for $9.95

If you select a book that counts as 2 choices, write the book number in one box and XX in the next. If you select a Counts as 3 choice, write the book number in one box and XXX in the next 2 boxes.

Name ______________________________

Address/Apt.# ______________________________

City ____________________ State______

Zip __________ Phone ____________________

Offer valid for new members only, subject to acceptance by EEBC. Canada must remit in U.S. funds drawn on U.S. banks. Applicants outside the U.S. and Canada will receive special ordering instructions. A shipping/handling charge & sales tax will be added to all orders.

©1993 EEBC IEEE593

Electronics Engineers' Book Club®

Get 3 Books for only $9.95

when you join the

Electronics Engineers' Book Club®

YES! Rush me the following titles, billing me just $9.95 (plus shipping/handling & sales tax). Enroll me as a member of the **Electronics Engineers' Book Club** according to the terms outlined in this ad. If not satisfied, I may return the books within 10 days without obligation and my membership will be cancelled. I agree to purchase just 3 more selections at regular Club prices during the next 2 years and may resign anytime thereafter.

Code #'s of my books for $9.95

If you select a book that counts as 2 choices, write the book number in one box and XX in the next. If you select a Counts as 3 choice, write the book number in one box and XXX in the next 2 boxes.

Name ______________________________

Address/Apt.# ______________________________

City ____________________ State______

Zip __________ Phone ____________________

Offer valid for new members only, subject to acceptance by EEBC. Canada must remit in U.S. funds drawn on U.S. banks. Applicants outside the U.S. and Canada will receive special ordering instructions. A shipping/handling charge & sales tax will be added to all orders.

©1993 EEBC IEEE593

Electronics Engineers' Book Club®

2962P $18.95 Softcover

3138H-XX $60.00 Counts as 2

009522H $49.00

012742H $26.95

9255H-XXX $105.50 Counts as 3

3540P $17.95 Softcover

062807H $50.00

070439H $60.00 Counts as 2

585261H $52.00

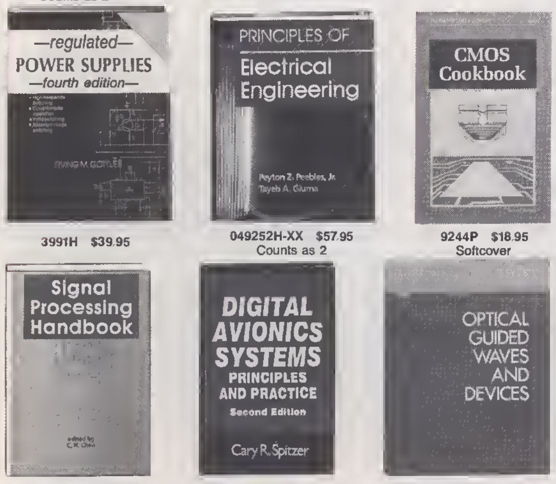
065443H-XX $65.50 Counts as 2

3710H $32.95

037504H $39.50

707463H-XXX $90.00 Counts as 3

586166H-XX $59.95 Counts as 2



3991H $39.95

049252H-XX $57.95 Counts as 2

9244P $18.95 Softcover

584760H-XXX $125.00 Counts as 3

060333H $50.00

707425H-XXX $50.00 Counts as 3

As a member of the Electronics Engineers' Book Club . . .

. . . you'll enjoy receiving Club bulletins every 3-4 weeks containing exciting offers on the latest books in the field at savings of up to 50% off of regular publishers' prices. If you want the Main Selection do nothing and it will be shipped automatically. If you want another book, or no book at all, simply return the reply form to us by the date specified. You'll have at least 10 days to decide. And you'll be eligible for *FREE BOOKS* through the Bonus Book Program. Your only obligation is to purchase 3 more books during the next 2 years, after which you may cancel your membership at any time.

If you select a book that counts as 2 choices, write the book number in one box and XX in the next. If you select a Counts as 3 choice, write the book number in one box and XXX in the next 2 boxes. All books are hardcover unless otherwise noted. Publishers' prices shown. ©1993 EEBC A shipping/handling charge & sales tax will be added to all orders. IEEE593

If coupon is missing, write to:
Electronics Engineers' Book Club, Blue Ridge Summit, PA 17294-0860

Circle No. 21

BUSINESS REPLY MAIL
FIRST CLASS MAIL PERMIT NO. 9 BLUE RIDGE SUMMIT, PA
POSTAGE WILL BE PAID BY ADDRESSEE
ELECTRONICS ENGINEERS' BOOK CLUB®
A Division of McGraw-Hill, Inc.
Blue Ridge Summit, PA 17214-9976
NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

Canadian Workshop on Information Theory (IT, Region 7); May 30–June 2; Le Riviera Conference Centre, Rockland, Ont.; T. Aaron Gulliver, Department of Systems and Computer Engineering, Carleton University, Ottawa, Ont., Canada K1S 5B6; 613-788-5734; fax, 613-788-5727.

JUNE

43rd Electronic Components and Technology Conference—ECTC '93 (CHMT); June 1–3; Buena Vista Palace Hotel, Orlando, Fla.; James A. Bruorton, Kemet Electronics, Box 5928, Greenville, S.C. 29606; 803-963-6621

International Symposium on Industrial Electronics—ISIE '93 (IA et al.); June–3; Hotel Agro, Budapest, Hungary; Okyay Kaynak, Bogazici University, Bebek, 80815 Istanbul, Turkey; (90+1) 265 9909; fax, (90+1) 257 5030.

International Symposium on Electron, Ion and Photon Beams (ED); June 1–4; Sheraton Harbor Island, San Diego, Calif.; Fritz J. Hohn, IBM Research Division, Thomas J. Watson Research Center, Box 218, Yorktown Heights, N.Y. 10598; 914-945-1608; fax, 914-945-4121.

IEEE-USA's Legislative Initiative Highlights Competitiveness and Pension Reform

IEEE's United States Activities Board launched a Legislative Initiative, a concentration of volunteer, staff, and budgetary resources, to promote two issues of vital concern to U.S. members—enhancing U.S. competitiveness and achieving pension portability. Begun in 1989, this effort continues today with a renewed focus on competitiveness and pension reform. As an election year, 1992 offered special opportunities.

The Campaign '92 Initiative
In 1992, IEEE-USA promoted jobs, economic growth, and competitiveness as election-year issues to raise public awareness of the role technology plays in promoting competitiveness. Presidential candidates George Bush and Bill Clinton responded to IEEE President Merrill W. Buckley's challenge to answer 10 questions outlining their plans for improving U.S. technological competitiveness. Their responses were highlighted in *The Institute* and *Professional Perspective*.

Enhancing U.S. Competitiveness
IEEE-USA's Competitiveness Committee pursued several special initiatives in 1992, including sponsoring a Competitiveness Fellow on the staff of Senator William V. Roth (R-Delaware) and two Technology Fellows to support the programs of the new Technology Administration in the U.S. Department of Commerce. With support from the National Center for Manufacturing Sciences, the Committee also developed draft legislation for introduction in Congress that would provide Government guarantees and low-cost loans for manufacturing production facilities in the United States. The Committee will renew its efforts in 1993 and join with the Technology Policy Council to promote passage of the *National Competitiveness Act*, H.R. 820 and S.4.

Promoting Pension Reform
IEEE-USA's Pensions Committee is pursuing changes in pension law to expand pension coverage and savings options, reduce vesting requirements, and improve pension portability. Member participation in letter-writing campaigns and Capitol Hill visits helped the Committee secure introduction of the *Pension Coverage and Portability Improvement Act* and the *Pension Reform Act* in the 102nd Congress, but election-year distractions discouraged positive Congressional action.

The Committee has crafted new legislation that focuses narrowly on pension portability and vesting, to broaden the base of political support for reform. Committee members are also seeking Congressional sponsors, lining up public support, and giving testimonies supporting full restoration of Individual Retirement Accounts to help advance the retirement security interests of IEEE's U.S. members.

You can learn more about IEEE-USA's legislative activities by contacting the IEEE-USA Office in Washington, D.C., for a copy of IEEE-USA's *Federal Legislative Agenda*. The Agenda summarizes IEEE-USA's recommendations to the 103rd Congress on such high priority public policy issues as competitiveness and pensions.

—*Chris J. Brantley*, Manager
Government Activities

Circle No. 12

From My Perspective

Cynical about change? As most people realize, change is simply a process, which may or may not produce progress. Some people believe that reorganizing is the best way to change any situation. Reorganization can be a wonderful activity for creating the illusion of progress while producing confusion, inefficiency, and demoralization.

Nothing is more difficult to undertake, more perilous to orchestrate, or more uncertain in its success than changing situations for the better. But times change, and we must change with them.

Change is not without inconvenience. So, while it is inevitable and linked to progress, change generates opposition. Change disturbs the even keel of life, which is not bad, if the new life is better than the old. But change also threatens vested interests.

If progress cannot be made without change, is the converse also true? In IEEE, our leaders want to be seen as always changing things. Action is the stuff of managerial myth. We want to see our leaders in the fray, not shrinking from decision-making. But fools rush in where angels fear to tread.

Some IEEE Boards, Councils, and Committees spend much time debating structure, organization, and mission. Many IEEE members view this self-examination as irrelevant, and it turns them off. Witnessing arcane debates is not why most engineers joined IEEE.

The Institute must project itself as a dynamic, progressive organization that is serving the professional needs of its members and the engineering profession. While change may be necessary to achieve such a goal, change for the sake of change is not progress. The debate on whether to change should not take up so much time that none is left to make the changes that will better serve members and their profession.

—*Michael J. Whitelaw, P.E.*
Editor in Chief

TPC Hosts Capitol Hill Briefings

IEEE-USA's Technology Policy Council hosted key Congressional policymakers at an electrotechnology policy issues briefing on Capitol Hill. Designed to introduce IEEE-USA volunteers and staff to new Members of Congress and their staffs, the event will inaugurate a new series of monthly Congressional seminars on technology policy issues.

The briefing featured three presentations. IEEE-USA Technology Policy Council (TPC) Chairman Joseph D. Bronzino stressed the need for a bioengineering emphasis at the National Institutes of Health. TPC Co-Vice Chairman J. Mark Pullen proposed a stronger role for the Department of Commerce in establishing U.S. technology policy, and Co-Vice Chairman Robert S. Powers discussed telecommunications as part of the national information infrastructure. ✦

PEER II Contract Canceled

IEEE-USA's Employment Assistance Committee (EAC) Chairman John E. Martin announced that EAC's contract with Success Systems, Inc., to operate the Professional Engineering Employment Registry (PEER II) will not be renewed.

"Both EAC and Success Systems worked hard to make PEER II a success, because it held out so much hope for our members," Martin said. However, he pointed out that the company has never been able to deliver what was promised in the PEER II brochure. The Committee felt that the product could not be improved sufficiently to satisfy IEEE's member-users.

Success Systems will continue to honor existing subscriptions to the service. Current subscribers will still be able to contact the company for additional diskettes of job listings, and their resumes will continue to be included in a data base searched by employers.

At this time, EAC has no plans to replace the employment registry, but the committee will provide members with a list of several existing commercial registries and data bases. IEEE-USA will continue to sponsor employment workshops, job fairs, local job banks, videotape libraries, local consulting networks, and other forms of employment assistance.

—*William R. Anderson*, Manager
Member Activities Council

Job Fairs Update

IEEE job fairs are tentatively scheduled at these locations during 1993:

DATE	LOCATION
May 3-4	San Jose Section (LG)
May 17-18	Detroit Section (LG)
June 7-8	Boston Section (LG)
June 14-15	Nat'l Capital Area Council (LG)
June 14-15	Detroit Section (PE)
June 21-22	Dallas Section (LG)
June 21-22	Santa Clara Section (W)
July 12-13	San Jose Section (LG)
August 2-3	Nat'l Capital Area Council (LG)
August 2-3	Detroit Section (LG)
August 16-17	Boston Section (LG)
August 16-17	Santa Clara Section (W)
September 13-14	San Jose Section (LG)
September 20-21	Nat'l Capital Area Council (LG)
September 20-21	Detroit Section (PE)
October 11-12	Santa Clara Section (W)
October 18-19	Cleveland Section (LG)
October 18-19	Boston Section (LG)
October 18-19	Dallas Section (LG)
October 25-26	Detroit Section (LG)

Job fairs are open to all engineers. For more information concerning the locations of the job fairs marked (LG), please call (800) 562-2820; Virginia residents should call (800) 533-1827. For fairs marked (PE), please call (800) 338-4530; and for fairs marked (W) call (408) 970-8800. In all cases, ask for the IEEE Career Fair Coordinator. ✦

The Pen Is Mightier Than the Scope Probe

While serving as Chairman of IEEE-USA's Intellectual Property Committee (IPC), I heard from engineers trapped in such bizarre situations as being forced to work without pay or to finish a patent application long after leaving employment. One employer was trying to claim a patent obtained before the inventor went to work for the company. During the years I have served on IPC, I have written articles, generated testimony for the U.S. Senate, visited Members of Congress and various Federal agencies, and spoken before groups about intellectual property issues.

Every committee within IEEE-USA's Career Activities Council is involved with the needs of practicing engineers. The committees include Pensions, Ethics, Licensure and Registration, Manpower, Career Maintenance and Development, and Anti-Discrimination, as well as Intellectual Property. They are not legal defense funds, nor can they dispense legal advice or negotiate with your employer. However, the committees can offer information, and they inquire into the dark recesses of our profession, which is often sufficient to initiate change.

Few things calibrated my duty as a committee chairman better than a horror story from an engineer. Members of Congress will listen politely to philosophical positions, but real examples of people being hurt impel them to action. In other words, you need to educate us to empower them.

Tell us about the lumps and bumps in your professional path. Write or call the IEEE-USA Office in Washington D.C., and the staff will guide you to the appropriate committee for help.

—*Orin B. Laney*, Editor
Career Activities Council

IEEE Leads National Engineers Week Activities

IEEE's lead sponsorship of National Engineers Week (NEW) 1993 culminated in a series of high-profile events held in Washington, D.C., during the week of February 14-20.

On Wednesday, February 17, the first NEW Future City Competition national finals were held at the U.S. Department of Energy (DOE). Martha Sloan, IEEE President and 1993 NEW Chairman, presided over a ceremony and press conference following the competition.

Tilden Middle School of Rockville, Maryland, was awarded first prize by DOE Secretary Hazel R. O'Leary. The school's computer design and scale model of a 21st century city that is energy efficient, environmentally sound, cost-effective, and people-oriented was judged best of almost 200 entries at the regional and national levels. The competition received wide TV, radio and newspaper coverage, including ABC Evening News footage of Sloan and the winning team at a White House meeting with President Clinton.

After meeting with their respective Members of Congress on Capitol Hill, finalists in the Future City Competition demonstrated their projects at a National Engineers Week Evening Gala at INTELSAT. This unique event brought together adults and children to celebrate the profession's present and future. Participants were treated to the "Marsville" project, a walk-through model of a human habitat on Mars created by local grade-school students. "Dr. Fad," the inventive PBS children's show personality, provided lively entertainment, and Sloan presided over a program that included presenting the Engineering Foundation's National Engineering Journalism Award to *The New York Times'* Jay Romano, and remarks by Kenneth T. Derr, Chairman of Chevron Corporation and Honorary Chairman of NEW 1993.

Also during the week, the profession was spotlighted in the nation's most influential print media. An IEEE-produced ad appeared in *The Washington Post* and *The New York Times.* In addition, Rep. George Brown (D-California) read a statement honoring the engineering profession into the *Congressional Record.*

—*Christopher R. Currie*, Consultant
IEEE-USA Public Relations

Recent books

Wisdom of the Elders. *Suzuki, David,* and *Knudtson, Peter,* Bantam Books, New York, 1992, 272 pp., $22.

Object-Oriented Software Engineering with C++. *Ince, Darrel,* McGraw-Hill, New York, 1992, 231 pp., $45.95.

Engineering field theory with applications. *Setian, Leo,* Cambridge University Press, New York, 1992, 354 pp., $80 (cloth), $34.95 (paperback).

Graphics Gems III–Macintosh. Ed. *Kirk, David,* Academic Press, San Diego, Calif., 1992, 631 pp., $49.95.

Multidimensional Processing of Video Signals. Eds. *Sicuranza, Giovanni L.,* and *Mitra, Sanjit K.,* Kluwer Academic, Dordrecht, the Netherlands, 1992, 188 pp., $95.

Impact of science on society, No. 165: Ergonomics, Vol. 41, No. 5, and No. 166: Environment and Development, Vol. 41, No. 6. Eds. *Howard J. Moore, et al.,* Unesco/Taylor & Francis, London, 1992, 108 pp. and 201 pp., published quarterly, subscription $72.

Graphics Gems III–IBM. Ed. *Kirk, David,* Academic Press, San Diego, Calif., 1992, 631 pp., $49.95.

Survey of Semiconductor Physics, Vol. II. *Boer, Karl W.,* Van Nostrand Reinhold, New York, 1992, 1472 pp., $79.95.

Borland C++ 3.0 Programming, 2nd edition. *Ezzell, Ben,* Addison-Wesley, Reading, Mass., 1992, 608 pp., $28.95.

Expert Database Systems: A Gentle Introduction. *Beynon-Davis, P.,* McGraw-Hill, New York, 200 pp., 1992, $35.95.

Alpha Architecture Reference Manual. Ed. *Sites, Richard L.,* Digital Press, Burlington, Mass., 1992, 600 pp., $34.95.

A Guide to RISC Microprocessors. Ed. *Slater, Michael,* Academic Press, San Diego, Calif., 1992, 328 pp., $49.95.

Simulation of Communication Systems. *Jeruchim, Michel C., et al.,* Plenum Press, New York, 1992, 731 pp., $110.

Electronic CAD Frameworks. *Barnes, Timothy J., et al.,* Kluwer Academic, Dordrecht, the Netherlands, 1992, 195 pp., $72.

Building Hypermedia Applications. *Howell, Gary Thomas,* McGraw-Hill, New York, 1992, 279 pp., $42.95.

Electrochemistry of Semiconductors and Electronics: Processes and Devices. Eds. *McHardy, John,* and *Ludwig, Frank,* Noyes Publications, Park Ridge, N.J., 1992, 300 pp., $64.

Telecommunication Circuit Design. *Van der Puije, Patrick D.,* John Wiley & Sons, New York, 1992, 351 pp., $54.95.

Pocket Book of Integrals and Mathematical Formulas. *Tallarida, Ronald J.,* CRC Press, Boca Raton, Fla., 1992, 225 pp., $14.95.

Systems Engineering. *Sage, Andrew P.,* John Wiley & Sons, New York, 1992, 606 pp., $69.95.

Synchrotron Radiation Research, Vols. 1 and 2. Ed. *Bachrach, Robert Z.,* Plenum Publishing, New York, 1992, 526 pp. and 398 pp., $115 and $95, respectively.

Introduction to Fields and Circuits. *Lancaster, Gordon,* Oxford University Press, New York, 1992, 395 pp., $39.95.

Program notes

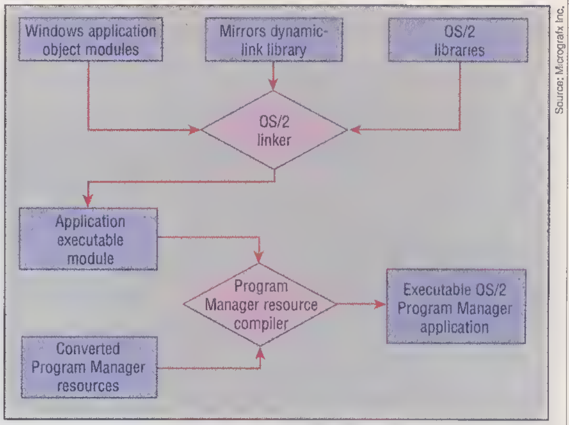
From Windows to OS/2 by Mirrors

Since graphical-user-interface (GUI) programs will run much faster under 32-bit OS/2 2.0 than under 16-bit Windows 3.1, many programmers are considering converting them to OS/2 2.0. This is a straightforward exercise since OS/2 grew out of Windows: both use function calls to dynamic link libraries (DLLs), and both store application resources—such as icons, bit maps, and help files—in separate files.

Given OS/2's limited market share, time-consuming manual conversion of applications is hard to justify. However, automated conversion software is available, which reduces the time required to convert a Windows application to OS/2 from weeks to days.

One package, Mirrors, was created by Micrografx Inc., the first software company to market a Windows application. Mirrors supplies tools that convert the resource, definition, and help files of Windows—as well as cursors, icons, and bitmaps—into OS/2 Program Manager (PM) files. The only manual activity left to the programmer is to convert source code.

Mirrors also helps programmers who want to create an OS/2 application directly from Windows source code. The converted resources and the existing source code may be relinked with the Mirrors DLL for OS/2 to produce an ersatz OS/2 application. (The Mirrors DLL can be thought of as a Windows emulator running under OS/2; it supplies OS/2 equivalents for common Windows functions like dialog boxes and control classes, and routes more complex calls for Windows DLLs to the equivalent OS/2 DLLs.)



Programmers who want to create an OS/2 application directly from Windows source code can do so with the Mirrors DLL for OS/2. Relinking converted resources and existing source code creates an ersatz OS/2 application.

Although a program generated by a manual OS/2 conversion will run faster than a program generated by the ersatz OS/2 conversion, either will be faster than a Windows application run under the OS/2 Windows compatibility box. And, since the ersatz OS/2 program is generated directly from Windows source code, it can be kept up-to-

(Continued on p. 18)

MULTISYNC COLOR MONITORS: THE MILLION-SELLING TREND-SETTERS.

Sales of NEC's MultiSync™ color monitors for personal computers have soared past the one million mark. MultiSync scored a smash hit when introduced in 1985 because it was a leading-edge monitor that offered auto-sync compatibility with various types of PCs and graphics boards. MultiSync was the first monitor to standardize the Super VGA video mode.

MultiSync continues to set the standard for PC monitors. Today's enhanced MultiSync displays are designed for graphics-intensive windowing environments. With flatter, squarer screens, they offer brighter, sharper, more accurate images.

MultiSync monitors in the FG Series also feature a unique color calibration system. The AccuColor™ control system allows users to adjust on-screen colors at will. The red, green and blue guns can be separately controlled in precise digital steps.

Advanced digital controls also automatically size and center screen images for preset and custom graphics modes.

Ergonomic features range from an improved cabinet design to a new anti-static, low-reflection screen. Reduced Magnetic Field™ technology lowers ELF and VLF emissions to meet Sweden's strict MPR II guidelines.

NEC's new MultiSync monitors are available in 15, 17 and 21-inch models.

NUMBER 150

INMARSAT-M PHONE IN A BRIEFCASE COVERS THE WORLD.

Reporters and aid workers have a new high-tech communications tool. NEC's compact INMARSAT-M phone provides reliable telephone and facsimile services to and from anywhere in the world.

The portable voice terminal for the INMARSAT-M satellite communication service consists of a transceiver, flat antenna, handset and rechargeable battery, all integrated in a briefcase-size unit.

It takes just minutes to set up the phone, using a visual indicator to align the antenna with the satellite. The terminal connects with GIII facsimile machines.

The new INMARSAT-M phone is about half the size, weight and cost of conventional INMARSAT-A terminals. It will become an indispensable tool for professionals working in remote areas where communications are unreliable or non-existent.

circle no. 7 for Inmarsat-M Phone

NEW ZEALAND LAUNCHES AIN SYSTEM.

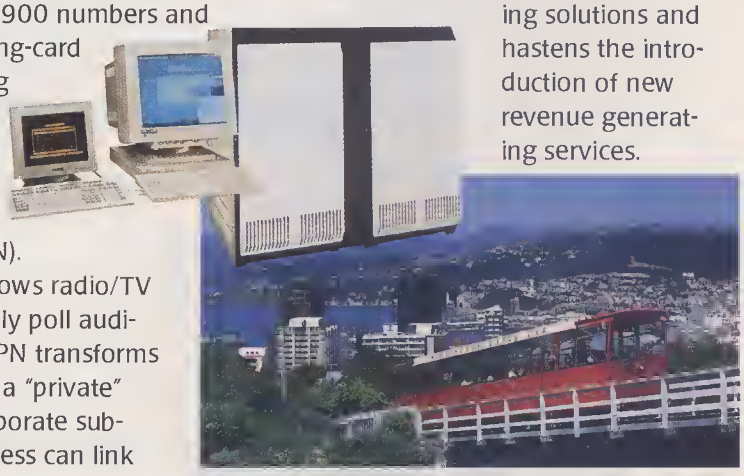
Telecom Corporation of New Zealand Limited has inaugurated an Advanced Intelligent Network (AIN), offering advanced services to subscribers across the country.

The system already provides enhanced 0800/0900 numbers and automated calling-card services. Coming attractions include televoting and virtual private networking (VPN).

Televoting allows radio/TV stations to rapidly poll audience opinion. VPN transforms public lines into a "private" network for corporate subscribers. A business can link branches nationwide. Employees call simply by dialing extensions.

New Zealand's AIN integrates NEAX61 switches installed in 296 exchange offices. AIN runs on NEAX61 application service processors using Stratus fault-tolerant computers and its software developed by NEC.

AIN demonstrates the scope and scale of systems that can be implemented with NEC's Customized Networking Platform (CNP). CNP provides optimum networking solutions and hastens the introduction of new revenue generating services.



VR4400 64-BIT RISC PROCESSOR.

NEC has introduced the industry's most powerful processor for workstations and servers. The new VR4400, an upgrade of the world's first 64-bit RISC microprocessor, runs at 150MHz internally and performs over 100 SPECMark.

Enhanced features include extra on-chip memory capacity. The VR4400 reduces power demands with singlechip configuration and 3.3V or 5V operation.

An easy design-in, the VR4400 is pin- and software-compatible with the VR4000. The open architecture supports both UNIX SVR4 and Windows NT.

NEC offers three versions: the standard VR4400 PC, the VR4400 SC with a secondary cache controller and the VR4400 MC for multiprocessor systems.

NEC

Program notes

(Continued from p. 15)

date with the Windows version, revision after revision, without having to invest a significant amount of time and effort. *Contact: Technical Support for Mirrors, Micrografx Inc., 1303 Arapaho, Richardson, Texas 75081; 214-994-6659; or* **circle 110.**

Smarter shapes for the inartistic

As 50–100-MIPS desktop machines become common, programmers need to rethink traditional programming techniques to ride hard on these millions of instructions per second (MIPS). Object-oriented operating systems like NextStep hint at the direction this rethinking may take—the realization that many of the complex procedures that make programming with operating systems difficult are no longer needed as the operating system becomes smarter. Application programs are starting to take up the object-oriented metaphor, too. One example is Shapeware's Visio, advertised as an "intuitive" drawing program for Microsoft Windows. It is aimed at those with minimal art skills who must prepare graphics for documents or presentations.

Visio uses a simplified "drop and drag drawing," in which all drawings are created from preexisting images called SmartShapes. The simplicity lies in the fact that the line shape, for example, knows when it is attached to the edge of another SmartShape and lengthens or shortens as the second shape is moved around the page.

The difference between Visio SmartShapes and the usual clip art is that each SmartShape has a description of itself stored in a graphics spreadsheet, called a ShapeSheet. Information on dimensions, angle and center of rotation, and styles that determine the appearance of the SmartShape are given in the ShapeSheet. Even equations can be included.

Users may also create new SmartShapes by creating ShapeSheets. *Contact: Shapeware Corp., 1601 Fifth Ave., Suite 800, Seattle, Wash. 98101-1625; 206-467-6723; or* **circle 111.**

A compiler for Pentium (a.k.a.'586).

Intel's new Pentium microprocessor (commonly called the '586) departs hugely from the 80xxx architecture of tradition. In fact, several articles in the trade press have claimed that programs created by a compiler developed specifically for the 80386/80486 will run more slowly on a Pentium microprocessor. To get the most out of the Pentium, apparently, programs will have to be recompiled using a compiler developed specifically for its architecture.

Watcom International Corp. has just announced the first 32-bit commercial Fortran compiler that can produce code optimized for Pentium, as well as the 80486 and the older 80386 central processing units. Watcom Fortran 77/386 v9.5. Version 9.5 is a hefty upgrade of Watcom's 32-bit compiler, which supports 32-bit DOS extenders, Windows 3.X, Windows NT, and OS/2 2.X. It ships with a debugger, profiler, royalty-free DOS-extender and Windows supervisor—plus necessary portions of the Windows Software Development Kit.

Existing Fortran number-crunching code recompiled with the 32-bit compiler may be linked to code compiled with Watcom's 32-bit C/C++ compiler. The combination creates powerful scientific software that will run on the most modern processor and take advantage of the latest features of new operating systems. *Contact: Intel Corp., 3065 Bowers Ave., Santa Clara, Calif. 95051; 408-765-4000; or* **circle 112.** *And: Watcom International Corp., 415 Phillip St., Waterloo, Ont., N2L 3X2 Canada; 519-886-3700; or* **circle 113.**

CONTRIBUTOR: John R. Hines is silicon sensors engineer at Honeywell Inc.'s MicroSwitch Division, Richardson, Texas.

Reflections

The performance rating

Even as the ancient cycle of sowing and reaping has recurred from time immemorial, so does the modern cycle of the work year. You put forth your best efforts for a good many months. Then there is a mysterious meeting of your managers known as the *performance review*, in which your pitiful efforts are judged. This is followed by the dreaded notification of your performance rating and the correspondingly inadequate raise. The theory is that you will reap what you have sown. That's the theory, anyway.

The reader will be shocked to learn that this process is imperfect. At least in agriculture, when you plant potatoes, you get potatoes. You may not get anything, of course, but you never get a turnip, for instance. Alas, in the world of business the laws of determinism do not apply. The wonderful seed that you have planted may have its beauty only in your own eyes. What you see as a potato may be judged to be a turnip, and thus a turnip it is. You would be well advised to discover in advance how this year's turnip crop will be perceived.

When the time of year is judged to be right—when the moon is pale and the frost gathers on the pumpkins—the managers in their great wisdom meet behind closed doors to perform their annual ritual. The assembled troops pace nervously in the corridors outside, awaiting the puff of smoke from the chimney that indicates decisions have been reached. Later, of course, these managers will themselves pace nervously as *their* managers gather behind closed doors. Nobody should miss the fun.

In its zealous quest for perfection, the human resources department changes the rules for the review every year. Whatever the process was the preceding year, it is now believed to have been a mistake. This is because management science finally knows the correct way to judge and motivate people through performance review.

In years gone by, people were largely spared the exact knowledge of their ranking. Of course, they might trade information about salary increases with others and make assumptions about where they might stand, but their rating was not a computable value. Then, later, when they were fired for nonperformance, they were greatly surprised and angered. "They never told me," was the cry of feigned disbelief.

Such anger, together with a court case or two, convinced the personnel departments of a basic law of human nature. It is: *people want to be told.* Thus the new rules were proclaimed. Everyone would be placed in a well-defined category with a specific label. There would be no ambiguity about how a person was performing in the organization. People would be informed of their rating.

In a typical exchange, the manager looks up nervously as John comes in for his annual performance evaluation. "Well, John, let's just get right down to business," he says. "Your performance this year has been found to be lacking in certain qualities that this company values. Consequently, when we assigned performance categories, you were placed in the, uh . . . the . . . well, what we have termed the 'turkey' category. Now I hasten to add that this rating may not be as bad as it sounds. You'll find the exact definition in our performance rating manual, but at least it places you above the 'lemming' category, where we would, ah . . . um . . . ask people to leave our employment."

> In its zealous quest for perfection, the human resources department changes the rules for performance evaluation each year

The supervisor looks quickly at his watch, and his eyes nervously glance toward the appointment calendar on his desk. "If your performance rating improves next year, John, I think you might be able to move up to the 'ostrich' rating," he says with an encouraging smile.

John frowns slightly, but the beginning of a smile starts around his eyes. "Thank you, sir," he says. "I am glad to be informed about this low rating." He glances calmly out the window at the trees in the parking lot, and there is a slight pause. "It is always good to know the truth," he finishes sincerely.

Fiction, isn't it? Let's get real. What does John actually say?

"What?!" cries John. "You've made a terrible mistake. What is the appeal process? I have a list right here of 133 significant accomplishments that I made last year. I want a transfer! You know what you can do with your rating. If anyone is a turkey around here, it's you!"

From conversations such as this, managers formed their own law of human nature. It is: *employees will reject the truth.*

Meanwhile, John goes back to his co-workers to begin his subtle campaign of subverting the rating system. After all, he's not going to tell his friends that he has been rated a 'turkey.' Instead, he stirs up conversation about the rating algorithm. "How do they come up with a rating around here?" he asks anyone who will listen. "Do they give you so many points for a patent and so many for a published paper? What happens if you're in a team that does some project? How do they divide the credit? They should tell us the exact algorithm that they use, so we'll know what counts. This whole process shouldn't be secret. We deserve to know."

From such conversations as this, the employees who are being rated form their own law of human nature to apply to the rating system. It is: *the "truth" is not the truth.*

Of course, not all employees are getting low ratings. Hank is one of the higher-rated people, but his wife senses an unusual quiet during dinner. It takes some gentle persuasion, but she finally gets him to confess that he was informed of his performance rating that day. "Well?" she persists. "How did they rate you?"

"I was classified as a 'superstar,'" he admits shyly.

"But that's fantastic!" she exclaims. "Why aren't you happy?"

"Well, they have these other people that they rate as 'megastars.' I didn't quite make the cut. It's really discouraging after all that I've done. Like, you know, Tom and Elaine—they're megastars, and I'm better than they are. I spent the afternoon bringing my résumé up to date. If the company doesn't appreciate me, I'll find someplace that does."

You would think that Tom and Elaine would be motivated by their fantastic performance ratings, but Elaine has heard a rumor that Tom is also a megastar, and she is seething inside. There should be more quantization in the rating system, she believes, so that the obvious gap in performance between her and Tom would be apparent.

Perhaps Tom is happy and motivated. It is not certain.

Robert W. Lucky

Computers and epidemiology

Analogies with biological disease, with topological considerations added, show that the spread of computer viruses can be contained

Computer viruses have bugged their hosts for half a dozen years or so. Massive outbreaks have been rare. But as society comes to rely ever more heavily on computers, contagious programs are beginning to seem nearly as frightening as biological diseases.

How bad is the problem today? How bad might it become? How might company managers help ensure safe computing environments? For answers to these questions, the behavior of computer viruses must be understood at two levels: microscopic and macroscopic.

The micro level is the focus of hundreds of researchers who dissect and try to kill off the dozens of new viruses written every month. Thanks to Fred Cohen's pioneering theoretical work, done in the early 1980s at the University of California, Los Angeles, computer viruses were understood in minute detail years before they posed even a slight threat.

In contrast, the macro view of computer viruses has lagged. The dearth of information about their prevalence was evident during last year's hullabaloo over the Michelangelo virus [see "The Michelangelo effect," opposite], during which estimates of its prevalence ranged over three orders of magnitude. Similarly, very few attempts have been made at modeling the spread of viruses mathematically, and most of these have contained serious flaws.

The situation is being remedied in two ways: by the collection of statistics from actual incidents, and by computer simulation of virus spread. This epidemiological approach—characterizing viral invasions at the macro level—has led to some insights and tools that may help society to cope better with the threat (and which may aid the study of biological viruses, too).

Jeffrey O. Kephart, Steve R. White, and David M. Chess
High Integrity Computing Laboratory
IBM Thomas J. Watson Research Center

Today, computer virus epidemiology is an emerging science that reveals that protective measures are definitely within reach of individuals and organizations. Among its findings:

• Computer viruses are far less rife than many have claimed. The rate of PC-DOS virus incidents for medium-sized to large businesses in North America appears to be about one per 1000 PCs per quarter. And fewer machines are caught up in a typical incident if anti-virus measures are in place.

• Few PC-DOS viruses have thrived. Less than 15 percent of the more than 1500 known viruses have ever been observed in a large sample population, and most of them only once. The top 10 viruses account for two-thirds of all incidents.

• Because software and diskette sharing tends to be localized, even successful viruses spread at nowhere near the exponential rate that some have claimed. This is good news for the anti-virus industry, which otherwise would have to distribute its software updates even more often.

• Centralized reporting and response within an organization is an extremely effective defense. These policies have more than halved the average incident size within the population monitored by IBM Corp., and can eliminate chronic infections that may afflict even conscientious organizations.

BIOLOGICAL ANALOGY. Biologists have combined the micro- and macroscopic perspectives on disease to good effect. It turns out that biological diseases and computer viruses spread in closely analogous ways, so that each field can benefit from the insights of the other.

Detailed statistics on disease proliferation date from mid-17th century London. The first major triumph for empirical epidemiology occurred there in 1854 when the city was suffering from a severe outbreak of cholera. Studying the spread of the intestinal disease over time led the physician John Snow to suspect that one of the local water supplies was to blame. A few days after the water source, at his suggestion, was shut down, the cholera epidemic subsided.

A theoretical approach to epidemiology was undertaken in 1760, when Daniel Bernoulli, one of the founders of mathematical physics, decided to model contagion mathematically. A controversial policy for controlling the spread of smallpox advocated inoculating healthy people with an extract derived from the disease's victims. The mortality rate from inoculation was about 1 percent, but those who survived emerged (after a relatively mild case) with lifelong immunity to smallpox. This was considerably better than the 20–30 percent mortality rate from ordinary smallpox, but it was feared that inoculation might ignite too many outbreaks and cause the death of many people who would not have contracted smallpox naturally.

Was the proposed cure worse than the disease? The answer could not be divined by intuition. Bernoulli evaluated the idea quantitatively by developing a mathematical model, using data from mortality tables to estimate its parameters. From a differential equation solution, he concluded that widespread inoculation would increase life ex-

Defining terms

Birth rate: the rate at which a virus attempts to replicate from one machine to another.

Computer virus: a program or piece of a program that, when executed, "infects" another part of a computing system by making a copy of itself. Most PC-DOS viruses infect boot records of disks, or executable programs.

Death rate: the rate at which a virus is eliminated from infected machines, usually when the user discovers it and cleans it up.

Epidemic: the widespread occurrence of a disease. A disease need not overwhelm a population to be epidemic; it must simply spread through some fraction of it.

Epidemic threshold: the relationship between the viral birth and death rates at which a disease will take off and become widespread. Above this threshold, the disease becomes a persistent, recurring infection in the population. Below it, the disease dies out.

Epidemiology: the branch of science that studies the spread of diseases.

Incident rate: the rate at which virus incidents occur in a given population per unit time, normalized to the number of machines (computers) in the population.

Infected machine: a computer that contains a virus, and can spread that virus to diskettes or other computers.

Prevalence: the degree to which a virus is widespread in a population.

Topology: in epidemiology, the patterns of contact along which diseases spread between individuals in a population.

Virus incident: the infection of a number of machines within an organization by a particular virus, due to a single initial infection from outside the organization.

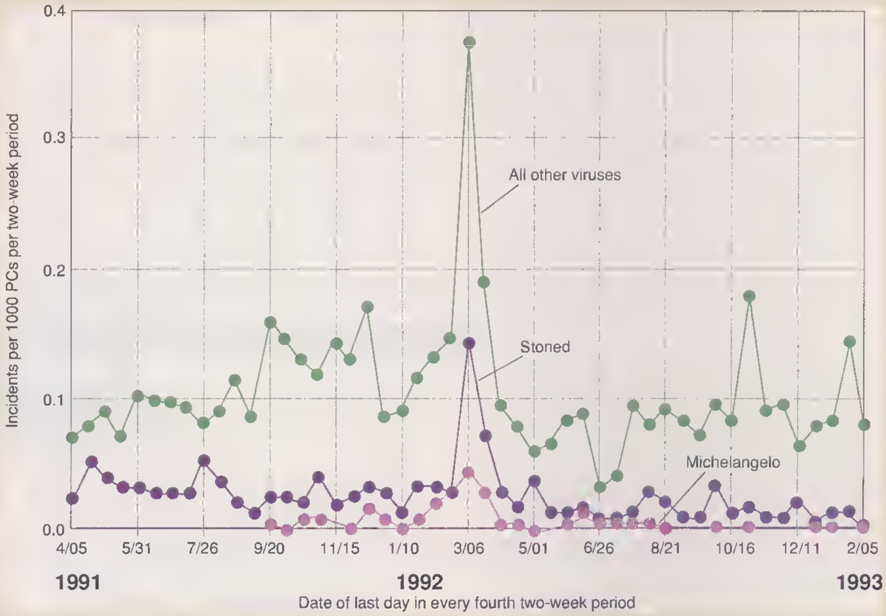
0018-9235/93/$3.00©1993 IEEE

The Michelangelo effect

Never has a computer virus stirred up so much public hysteria as during the two-week period ending on March 6, 1992.

Front-page newspaper stories and evening network news shows clamored that a nefarious virus was ready to disrupt computers on the March 6 birthday of Michelangelo. The public was persuaded this indeed might be the big one—the electronic equivalent of the bubonic plague—with millions of machines infected.

In fact, the number of machines infected by the Michelangelo virus was orders of magnitude less than one widely quoted estimate of five million, and the damage it caused was slight. But, as shown in the graph at right, all the publicity had an interesting effect on all computer viruses, including Stoned, the one most common at the time.



The rate at which incidents in the population sampled by IBM were reported peaked anomalously during this period, not because they actually surged, but because many viruses that had been infecting machines for some time were finally detected. Many users (both inside and outside the sample population of hundreds of thousands of PCs) decided to scan their systems out of concern about the Michelangelo virus. In some cases, companies spent large amounts of time and money doing so. The scanners found any recognizable virus in the system, such as Stoned. Consistent with this much heightened vigilance was the detection during the four weeks prior to March 6 of eleven new viruses in the sample PC population—a record high.

The hysteria had two effects on computer viruses. First, because many users scanned their machines during the same period, the reservoir of viruses was depleted both inside and outside the sample population, and many fewer virus incidents were reported in the succeeding weeks. Second, the increased installation of anti-virus software appears to have lowered the equilibrium level of many of the most common viruses, about halving their previous prevalence. Still, despite some beneficial side effects, this kind of hysteria is better avoided.

—J.O.K., S.R.W., and D.M.C.

pectancy by three years. (A new type of inoculation soon made his analysis moot, however.) Thus the macroscopic approaches of Snow and Bernoulli proved their value even before bacteria and viruses were found to be the cause of disease, late in the 19th century.

Not until the 1930s, with the advent of electron microscopy and X-ray crystallography, was a start made in elucidating the structure of biological viruses. Their life cycles and biochemistry have been studied intensively since the mid-1940s and have been used in tandem with epidemiology to prevent diseases. The greatest victory of this collaboration was the eradication of smallpox in 1977. Rather than attempt to immunize the entire world's population, the World Health Organization collected information about outbreaks and saw to it that only those likely to be in contact with an infected individual were immunized.

Today, the last specimen of the once-mighty virus—which mothered the invention of inoculation in 10th century China and Bernoulli's invention of mathematical epidemiology—is serving a life sentence in a maximum security facility at the Centers for Disease Control and Prevention in Atlanta, Ga.

For computer viruses, the microscopic view came first, in part because their detailed function and structure is much easier to comprehend than those of biological microorganisms. The world of bits and bytes is, after all, man-made. Computer scientists have no need of sophisticated and expensive tools like electron microscopes, gene sequencers, and graduate students to explore the inner workings of computer viruses. They are happy with a disassembler, a quiet room, and a few minutes or hours of staring at the virus program logic.

The synergy between the micro and macro views in biology has generated many of the 20th century's most important medical advances. The hope is that a science of computer virus epidemiology will benefit from the same synergy.

CONSTRUCTING A THEORY. Many, including Cohen and W.H. Murray, a well-known expert in computer security, have suggested applying theories of the spread of disease to computer viruses as well.

One of the simplifications worth borrowing from the biologists is to regard individuals within a population—in this case, computers and associated hard disks, diskettes, and other storage media—as being in one of a few discrete states, such as "susceptible" or "infected." Details of the disease within the individual are ignored (for instance, which executable files are infected within the computer).

In epidemiological language, pairs of individuals have "adequate contact" with each other whenever one would have transmitted a disease to the other if the first had been infected and the second had been susceptible. What constitutes adequate contact can vary quite considerably from one computer virus (or biological disease) to another. The birth rate of a virus is the frequency with which adequate contact occurs.

Offsetting the birth rate is the death rate of the virus —the frequency with which an individual is cured of the infection. Depending on the disease in question, an individual may become immune to it after infection or, at the other extreme, may become susceptible to it again immediately.

The birth rate of a computer virus is influenced by anything that hinders or promotes its replication, including intrinsic mechanisms by which the virus infects programs, the rate of software transfer among computers, and precautions taken by users such as the use of a write-protect tab on a diskette or preventive anti-virus software. The virus's death rate is influenced by intrinsic characteristics that might disguise or reveal its presence, by user awareness and vigilance, and by its detection and subsequent removal.

Just as an epidemiological model could be formulated by Bernoulli long before anyone knew the cause of smallpox, so the computer virus model is independent of what determines these rates. The only need is to be able to estimate the rates from empirical data.

A universal feature of the macro models is that, regardless of their specifications, they behave very differently on either side of a sharp threshold (the point at which an epidemic either takes hold or fades away). In the most common models, a virus can spread appreciably among the population

only if its birth rate exceeds its death rate.

Such a situation can be shown in a simple simulation of a population of 100 machines [Fig. 1, main graph]. Here, an infected machine can infect any other machine directly, and the virus's birth rate is five times its death rate. Exposure creates no immunity; machines may be reinfected immediately after they are cured.

Initially, just one machine is infected. As the simulation begins to run, the number of those with the virus grows exponentially, but levels off when about 80 percent are infected. In this state of equilibrium, four out of five adequate contacts produce no new infection, because the victim is already infected. So, once this level is reached, the rate at which new infections occur exactly balances the death rate. The equilibrium level depends upon the ratio of the birth and death rates, and can take on any value between zero and 100 percent.

In some simulation runs, the virus is unlucky and dies out before it spreads very far. This happens when the virus is found and removed before it has reached more than a few machines. The extinction probability is equal to the death rate divided by the birth rate—meaning 20 percent in this case.

On the other side of the threshold, where the death rate exceeds the birth rate, the virus will be driven to extinction unless some other reservoir of infection periodically reinjects the disease into the population. But this will at worst result in small, short-lived outbreaks with an average size independent of the population size. The inset in Fig. 1 shows such a situation, where all the parameters are as before, except that the viral birth rate is only 90 percent of the death rate.

REAL WORLD CORRELATION. The powerful concept of an epidemic threshold was discovered by mathematicians early in this century. A few years ago, an analysis of simple models suggested that the same concept should also apply to the spread of computer viruses. And indeed, the existence of an epidemic threshold is strongly supported by statistics of thousands of virus incidents over the last five years in the large sample population tracked by IBM. This unique database is compiled continuously, as infections occur, from hundreds of thousands of DOS personal computers; the sample is international but U.S.-biased, and is typical of virus-conscious Fortune 500 companies.

In cooperation with other virus collectors around the world, IBM's High Integrity Computing Laboratory maintains a collection of PC-DOS viruses, currently including more than 1500 different specimens. Less than 15 percent of them have been observed in the large sample population, and these have rarely appeared more than once.

The 10 most frequently observed viruses in 1992 accounted for two-thirds of all incidents [Fig. 2]. The top two—Stoned and Form—accounted for about one-third of the total.

In some cases, computer viruses hardly spread at all, because they are below the epidemic threshold. This concept of epidemic threshold is perhaps the first good news that has been derived from theoretical studies of computer viruses.

An early theoretical result, derived by Cohen, was distinctly depressing. He found that an algorithm capable of distinguishing perfectly between viral and nonviral programs is a logical impossibility. Fortunately, his elegant proof [see "No virus detector is perfect," p. 24] has not halted the development of reasonably good software protection against today's computer viruses.

A popular but misleading theory of virus replication would have one quarter of the world's 100 million PCs already infected

MORE GOOD NEWS. For the unattainable goal of perfect detection, the threshold theory substitutes the achievable goal of pushing viruses below the epidemic threshold. It is encouraging that this has already been achieved for many viruses.

Once a virus has fallen below the epidemic threshold, further effort offers diminishing returns (although it does reduce the size of any outbreaks due to reintroduction of the virus from another reservoir, such as infected diskettes in a forgotten desk drawer).

But Cohen's proof cannot be dismissed so easily. Even as workers wipe out one virus, others are being written, some of which are likely to be above the epidemic threshold until anti-virus software is modified to deal with them.

COMMON DEFENSES. The anti-virus technologies differ in their effects on viral birth and death rates. The virus scanner, the most common, works by examining stored programs for infection with one of a set of known viruses. Scanners often also detect slight variants of known viruses. Some even incorporate a heuristic function, which allows them to detect some brand-new viruses by guessing at the function of the code.

Scanners excel at raising the virus death rate. Someone who installs a scanner and uses it at regular intervals—say, once a week—increases the death rate from nearly zero to at least, in this case, once a week. A resident scanner, which is always active in the system examining all programs that are loaded, pushes the death rate even higher, since the virus is detected (and presumably removed) as soon as it is loaded.

Scanners can also act as filters to decrease the viral birth rate. For example, if all new programs arriving at a machine are scanned as they arrive, the effective birth rate of the machine's neighbors will be lower.

Traditional access control systems are a second kind of anti-virus technology. By preventing unauthorized programs from altering other programs, they can decrease the viral birth rate. Networked systems lacking access control could be swamped by a virus within an hour or two. In his early experiments, however, Cohen showed that even when access controls are in place, viruses can spread quickly and widely without violating those controls.

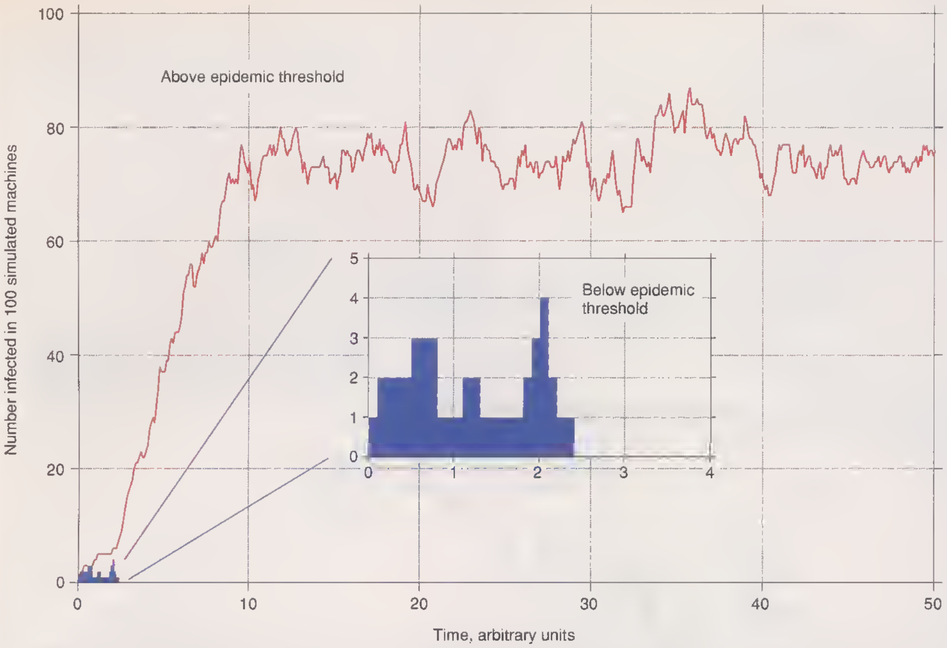
A third anti-virus technology, sometimes called integrity management, lies somewhere between scanners and access control systems. Its strategy is to detect and prevent virus spread by noticing or preventing the changes viruses make to parts of the computer system. An integrity management system can increase the viral death rate if it notices an anomaly due to a virus and alerts the user. Conversely, the system may note but not warn the user of a change (perhaps because the virus has noticed the protection and has not tried to spread), in which case it is limiting the birth rate.

While scanners work best against known viruses, integrity management systems can guard against larger classes of viruses. Because they look for general methods that viruses use to spread, not for the bit patterns that make up the virus code, they can be more effective on newly devised infectors. Their disadvantage is that they also flag or prevent legitimate activity, and so can disrupt normal work or lead the user to ignore their warnings altogether.

INDIVIDUAL AND COMMUNITY. By using both preventive and curative anti-virus technology in tandem, an individual protects his own machine more effectively than by using either technique alone. (Simple mathematical models suggest that the synergy is much stronger than one might guess.) An individual who protects a system out of self-interest also benefits the community by reducing the chance of a virus spreading to other systems.

The importance of lowering a virus's birth rate and raising its death rate is well understood by public health officials. Healthy children are inoculated against measles and tuberculosis patients take medication in part to protect everyone they come in contact with. If the steps taken by individuals put society as a whole below the epidemic threshold, then even the unprotected are unlikely to become infected.

Of all of the assumptions woven into the fabric of biological epidemiology, the least applicable to populations of computers is "homogeneous mixing": the supposition is



[1] Simulation shows that viruses can proliferate [main graph] or die quickly [inset], depending on whether the population is above or below the epidemic threshold. In the main graph, the birth rate is five times the death rate. The number of infections rises fast and plateaus at about 80 percent of saturation. (The average duration of infection is one time unit here and in Fig. 4.)

that every individual in the population is equally likely to infect or be infected by every other individual. But most individuals exchange most of their software with just a few others and never contact the majority of the world's population. Also, their exchanges tend to be localized: if Alice swaps software often with Bob and Carol, chances are that Bob and Carol swap software, too.

What is missing from standard epidemiological theories is this notion of topology—the pattern of interaction between individuals within a population.

Topological effects are incorporated into epidemiological models by representing individuals as nodes and their contacts as lines connecting the nodes. Each line can be characterized with its own viral birth rate, and each node with its own death rate.

Taking topology into account (and it could be useful in biological epidemiology as well) radically changes the picture of how viruses can spread. An enhanced frame from one of millions of simulations that have been conducted [Fig. 3] shows 250 individual systems out of a total of 10 000 in the population. In this example, the individuals tend to form hierarchically nested groups, with the members of one group exchanging software frequently among themselves, less often outside their department, and even less often outside their organization. The topology in this example is also sparse; each individual is in contact with only a few others.

First, consider the effect of sparsity. Suppose each individual has potentially infectious contact with 52 randomly chosen neighbors. They interact randomly on average once a year with each neighbor. Now imagine a sparser topology in which each individual has just one neighbor, contacted on average once a week.

In both cases, the overall birth rate is once per week. Analysis and simulation show that in the first scenario the epidemic threshold occurs when the death rate equals the birth rate—once per week. (This is precisely what the homogeneous mixing approximation would predict.) In the sparser topology of the second scenario, analysis and simulation show that an epidemic can occur only if the death rate drops below three per week. In general, bottlenecks hamper viral spread in sparse topologies, to the extent of preventing it entirely or making it less pervasive than in dense topologies.

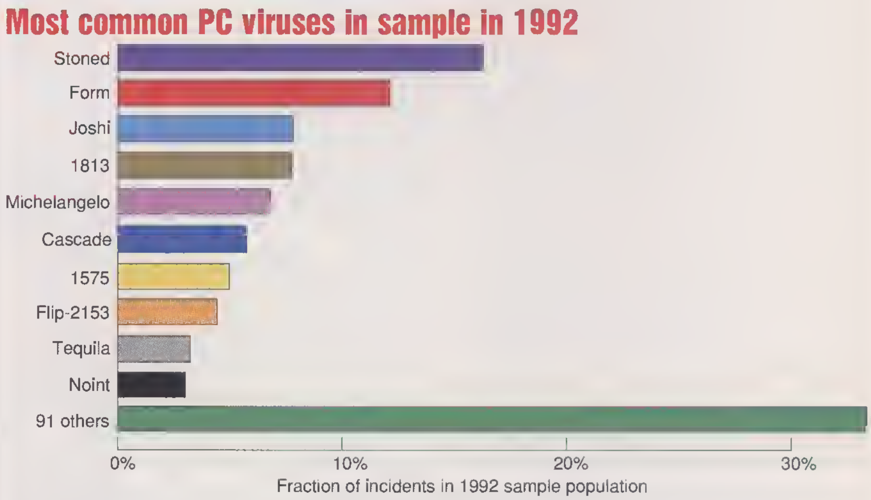
Localization has a different effect. Viruses spread more slowly in localized than in randomized or homogeneously mixed environments, in which growth is at first exponential [Fig. 4]. In another type of local topology—the two-dimensional lattice—the virus's growth is at first merely quadratic. Strongly sub-exponential spread rates occur in local topologies because the virus is forced to circulate in areas that it already occupies, limiting its access to healthy populations.

In some local topologies, such as those in Fig. 4, the equilibrium is essentially the same as in a homogeneous system. In others, it is much lower, and in yet others, the number of infections fluctuates wildly, never seeming to reach any sort of equilibrium.

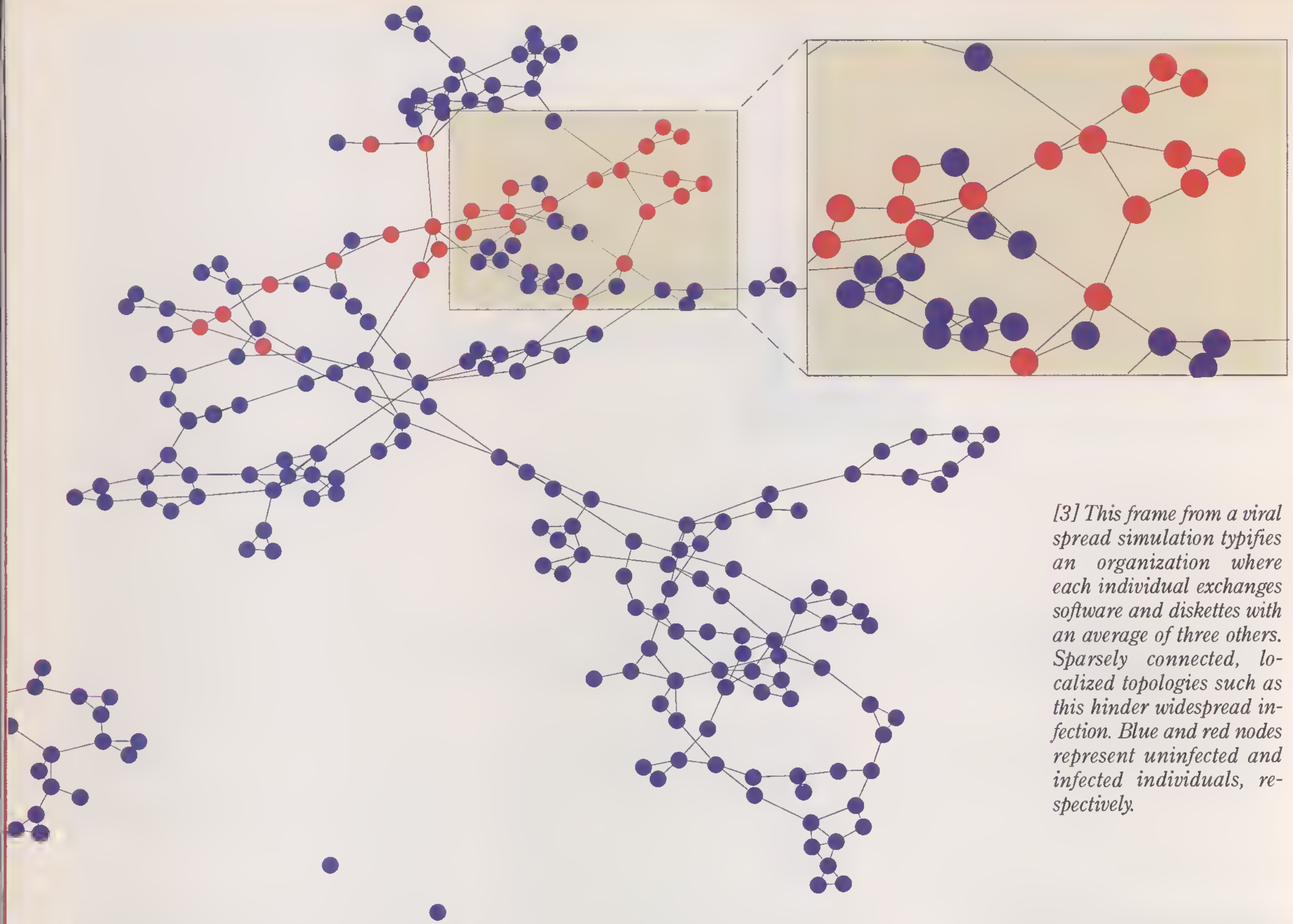
CASE STUDY. Virus incident statistics collected from the sample population are very revealing about how quickly viruses are spreading in the real world and how prevalent they have become. It so happens that the number of infected PCs in the world is roughly proportional to the number of incidents observed in the sample population.

What is the proportionality constant? It can be estimated for North American business sites with 100 or more PCs. This sector of the world was studied by the 1991 Virus Prevalence Survey conducted by Dataquest Inc., the market research firm in San Jose, Calif.

Two conclusions may be drawn by reinterpreting the raw data, which was supplied by Peter Tippett of Certus, a division of Symantec, namely, that the incident rate was about the same as in the sample population, and that an average of about three or four were infected in the course of an incident. Thus a rough estimate of the rate at which a given virus infects machines in this type of environment can be obtained by multiplying the measured incident rates by a factor of three or four.



[2] Most incidents in the large IBM PC sample are caused by a small percentage of the more than 1500 known viruses. The data shown are for 1992.



[3] This frame from a viral spread simulation typifies an organization where each individual exchanges software and diskettes with an average of three others. Sparsely connected, localized topologies such as this hinder widespread infection. Blue and red nodes represent uninfected and infected individuals, respectively.

Figure 5 shows the observed incident rates as a function of time for some of the most common viruses. During 1990 and 1991, the Stoned, 1813 (also known as Jerusalem), and Joshi viruses proliferated at a far less than exponential rate (perhaps roughly linearly) for a year or two. Then they leveled off at a few incidents per 10 000 PCs per quarter.

The Form virus began slowly, but in the third quarter of 1991, it began to take off as strongly as the Stoned virus had in early 1990. It is rumored that the Form invaded the master diskette used by a software distributor. The diskette duplicator may have saved the virus the trouble of copying itself, injecting maybe thousands of infected diskettes into the world. This blunder could easily have given Form the impetus to surpass Stoned last summer, when it became the world's most prevalent virus.

None of the viruses in the IBM sample population is multiplying at anything like an exponential rate, supporting the intuitive notion that software exchange is highly localized. This is good news. One widely publicized theory of computer virus replication implicitly assumed homogeneous mixing, predicting exponential growth for all viruses. In 1991, its author estimated that the 1813 (Jerusalem) virus had an exponential doubling time of, at most, 2.6 months, and a population of at least 500 as of October 1989. Extrapolating from this, by April 1993 over 25 million PCs—one fourth of the world's total—would be infected by the 1813 virus!

Because of the nature of the virus, that level of infection would have crippled the PC-DOS world because a bug in the 1813 virus causes it to reinfect some programs. Acquiring 1813 additional bytes every time they become infected, these programs eventually overflow the conventional 640 kilobytes provided by DOS, and can no longer run. Fortunately, the prediction of runaway infection was wildly inaccurate. In fact, Fig. 6 suggests this virus is on the decline, and that the war of 1813 is turning in the community's favor.

That even the most common of viruses are not very common is also good news for users. Just before the Michelangelo scare in early 1992, the Stoned incident rate appeared to be leveling off at 0.2 incident per 1000 PCs per quarter. Assuming that each virus incident affects three or four machines, Stoned was infecting under 0.8 of every 1000 PC-DOS machines per quarter in business environments. To obtain the fraction of machines infected with Stoned at a given moment in time, this 0.8 should be multiplied by the average duration of infection. Assume (generously) that this is half a year. Then far fewer than 1.6 in 1000 of these machines would have fallen prey to Stoned at any given moment during late 1991. In certain other environments, such as universities, the average incident size and duration may be much larger; the percentage of infected machines would be correspondingly higher.

As pleasing as it is to users and the anti-

No virus detector is perfect

In his pioneering theoretical study of computer viruses, Fred Cohen demonstrated that there is no general procedure that can discriminate perfectly between viruses and non-viruses. He used the following informal argument:

Suppose that there is a general procedure D which takes any given program P as input and returns the value *true* if and only if P is a virus. Now consider a program P that contains the following logic:

```
if (D(P) = false), then
    infect some chosen executable
if (D(P) = true), then
    do not infect anything
```

Thus P is a virus if D says it is not, and P is not a virus if D says it is. By contradiction, such a general procedure D is not possible. (A more rigorous proof appears in Cohen's Ph.D. thesis from the University of California, Los Angeles, in 1983.)

—*J.O.K., S.R.W., and D.M.C.*

virus community, the low level at which viruses plateau is puzzling. The simplest models yield as low an equilibrium only when the birth rate barely exceeds the death rate. Can every single one of the most successful viruses be so delicately balanced on the edge of becoming epidemic? What mysterious force is preventing rampant plagues? Something important is surely missing from the simple model.

Perhaps it's the human element. When a person encounters a computer virus, or hears a colleague has fallen victim to one, he or she becomes more vigilant (most probably through the purchase of anti-virus software). Unlike exposure to biological diseases, contact with one computer virus can actually confer immunity on all the computer viruses the anti-virus software can handle. Next, victims sometimes tell their friends, who then rush to check their own machines for infection. New models incorporating this effect show that word of mouth is surprisingly powerful even when not used to its full extent. A similar principle can engender successful anti-virus policies, as shall be seen shortly.

STEPS FOR COMPANIES. The new understanding of viral epidemiology can enable effective antiviral policies for companies. From a company's perspective, its machines are under constant attack from the outside world [Fig. 6 again]. Sooner or later, a computer virus will find its way inside. The rate at which this occurs depends on the number of infections in the world, the number of company machines, the frequency of software exchange between the company and the outside world, and the effectiveness of the company's precautionary measures.

The invasion marks the beginning of a virus incident. The virus may then spread to several more computers within the company before it is discovered. Once all the machines it has infected are found and cleaned up, the incident is over. The total number of machines infected is referred to as the size of the incident.

An organization should have two complementary goals: to reduce the influx of viruses and to stop those that get in from spreading. Epidemiology has much to say about how the second objective should be achieved.

The best approach a company can take today is to encourage users to inform a central agency about their machines' infection, and to have the central agency respond by helping those users clean up their machines and then check neighboring machines for infection. The sample population tracked by IBM has been doing this for several years. (It is a shame that some organizations do exactly the opposite: punishing employees whose machines are found to be infected!)

The effect of this policy can be dramatic.

Complete eradication of all viruses is impossible, but they can be reduced to the nuisance level

Suppose that the company has no organized anti-virus policy. It is likely that Form, Stoned, and other viruses that are above the epidemic threshold in the rest of the world will also be above the threshold inside the company. Once such a virus gets in, it has the potential to ignite a pervasive, persistent infection similar to the above-threshold case of Fig. 1. Even companies that have distributed anti-virus software widely within their organizations could be at risk.

With effective central reporting and response—where the entire incident is cleaned up as soon as any machine is found to be infected—the situation is similar to the below-threshold case in Fig. 1. Mathematical analysis shows that this occurs even if the virus's birth rate exceeds its death rate. There are two desirable consequences. First, the average incident size remains quite small, no longer scaling with the size of the organization. Second, the incident is finite in duration, rather than infinite.

Experience confirms the value of central reporting and response, coupled with the dissemination of anti-virus software. While these policies were being instituted within the sample population, the average incident size was 3.4 PCs. More than five PCs were involved in 12 percent of the incidents, but these large incidents were responsible for 60 percent of all machine infections [Fig. 7].

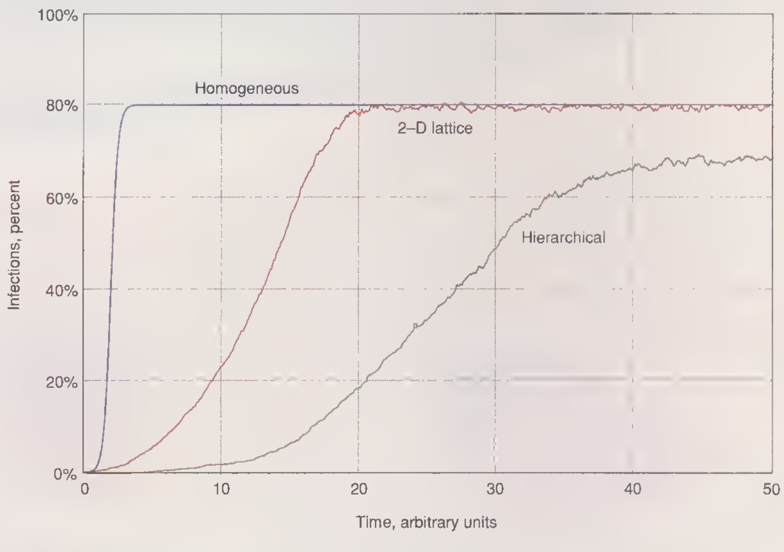
Once the policies were firmly in place, the percentage of large incidents fell. In 1992, the average incident size was less than 1.6 PCs. Only 2.5 percent of the incidents were large, and they accounted for just 27 percent of all machine infections [Fig. 8].

Even within the sample population, infections sometimes persist in an organization. When the number of reports of a particular virus in a particular location is well above the statistical average, the virus may be spreading internally, rather than penetrating repeatedly from the external world. Resources can then be marshalled to help that organization quell the incident.

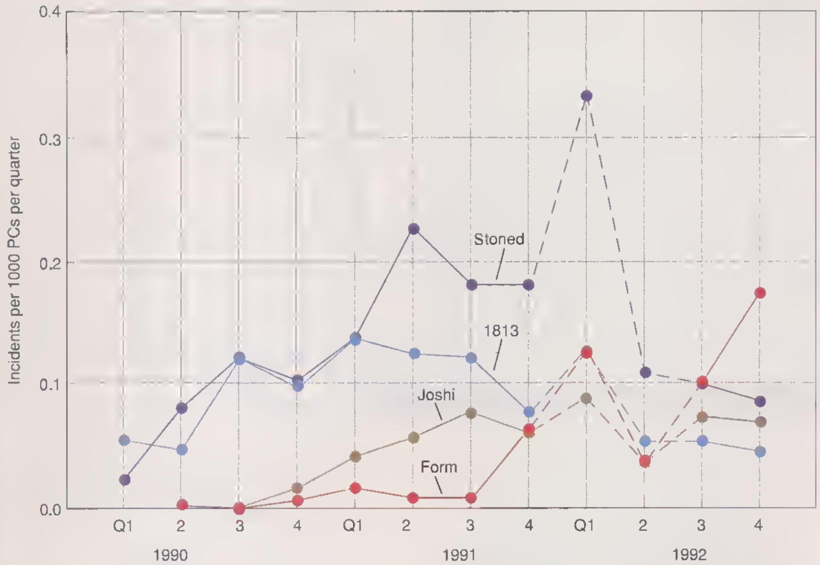
Accurate statistics thus help a company to focus its anti-virus resources on the areas that need them most, keeping costs down. They also help a company to monitor its own progress in reducing the influx of viruses (through the measured incident rate) and in limiting internal spread (through the measured average incident size).

As a final, powerful argument for central reporting and response, recall the World Health Organization's sensational victory over smallpox, in which an analogous strategy of well-targeted immunization played a key role.

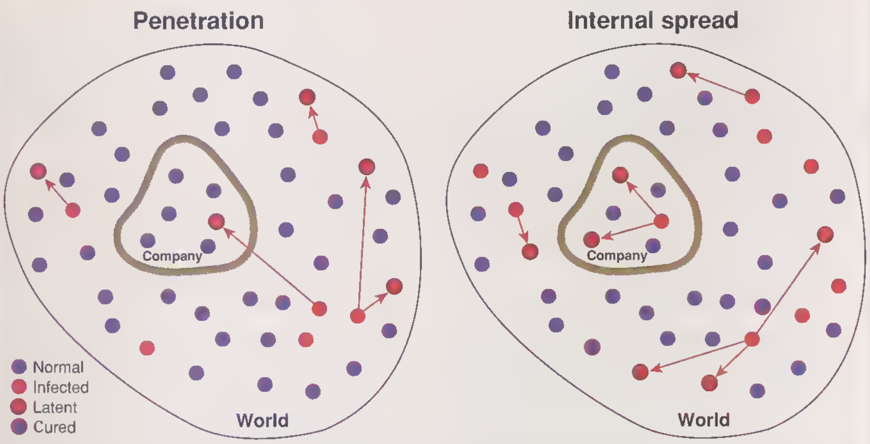
PROSPECTS. The new science of computer virus epidemiology has already yielded a much better understanding of viral spread, the factors governing it, and how to control it. In order to make theories more quantitative and predictive, ways must be found of characterizing the world's software exchange. From user surveys and automatic monitoring techniques, we hope to learn enough about individual behavior to further influence virus trends occurring within organizations and indeed throughout the world.



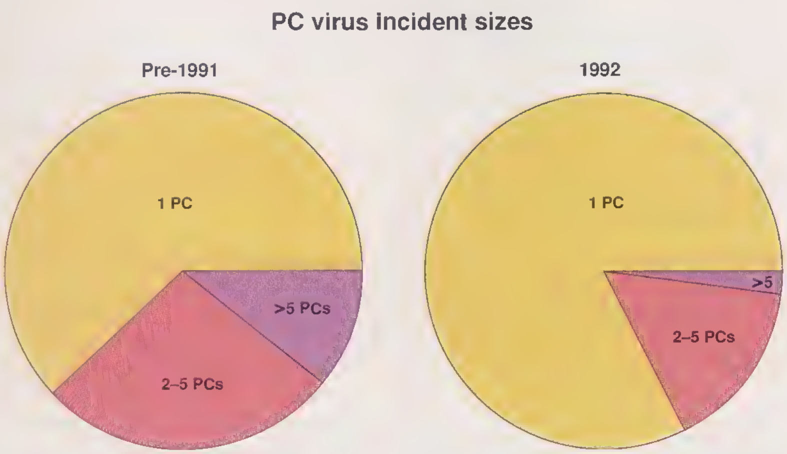
[4] The extent to which a virus spreads depends strongly on the degree of localization of the patterns of interaction. In each simulation run, one of approximately 10 000 individuals was infected initially, and the birth rate was five times the death rate.



[5] Incident rates of the four most common viruses of 1992 reflect their worldwide prevalence over time. The good news is that viruses seem to peak at relatively low levels. An anomaly in early 1992 was due to the Michelangelo effect.



[6] From an organization's perspective, viruses will occasionally infiltrate [left], starting a virus incident that may spread [right]. Organizational vulnerability is determined by the fraction of infected machines in the world, the number of machines in the organization, and the organization's success in detecting and eradicating such incidents.



[7] Anti-virus policies can work. During a six-month period, while implementation was being begun at organizations in a sample population [left], 12 percent of incidents spread beyond five machines. Once procedures were well-established [right], only 2.5 percent grew as large.

Complete eradication of all viruses is impossible as long as there are malicious programmers. Combining microscopic and macroscopic solutions, however, holds out the hope of reducing the problem to the nuisance level.

TO PROBE FURTHER. The microscopic view of biological viruses can be found in *Viruses*, by Arnold J. Levine (Scientific American Library, W. H. Freeman, New York, 1992). The macroscopic view of diseases is described in *Plagues and Peoples*, by William H. McNeill (Doubleday, New York, 1977).

The classic textbook on mathematical epidemiology is Norman T.J. Bailey's *The Mathematical Theory of Infectious Diseases*, now in its second edition (Oxford University Press, New York, 1987). An illustrated account of modern-day practical epidemiology is given in the article "The Disease Detectives," by Peter Jaret, *National Geographic*, January 1991, pp. 114–140.

Computers & Security, Vol. 6 (February 1987) contains the article by Fred Cohen that defined computer viruses as they are known today: "Computer Viruses: Theory and Experiments," pp. 22–35.

IEEE Spectrum previously examined data security in general, and the microscopic view of viruses in particular, in a multi-part special report in August 1992.

More detailed versions of the authors' macroscopic virus studies can be found in the *Proceedings of the 1991 IEEE Computer Society Symposium on Security and Privacy*, Oakland, Calif., May 20–22, 1991; in the *Proceedings of the Fourth and Fifth Annual Computer Virus and Security Conferences*, New York City, March 14–15, 1991, and March 12–13, 1992; and in the *Proceedings of the Second International Virus Bulletin Conference*, Edinburgh, Scotland, Sept. 2–3, 1992.

ABOUT THE AUTHORS. Jeffrey O. Kephart is a research staff member of the High Integrity Computing Laboratory at the IBM Thomas J. Watson Research Center, Hawthorne, N.Y. After earning a B.S. from Princeton University and a Ph.D. from Stanford University, both in electrical engineering, he spent two years with the Dynamics of Computation Group, Xerox Corp.'s Palo Alto Research Center (PARC). At IBM, he pursues theoretical and practical anti-virus research. (He may be reached by e-mail: "kephart@watson.ibm.com".)

David M. Chess, also a research staff member at the laboratory, joined IBM in 1981 after receiving an A.B. in philosophy from Princeton. His current research interests include virus protection and the implications of self-replicating phenomena for distributed systems.

Steve R. White is manager of both the laboratory and the Distributed Security Systems Group at the IBM research center. At IBM since 1982, after earning a Ph.D. in theoretical physics from the University of California, San Diego, he holds several patents in security-related fields. ◆

Blue lasers on the horizon

Lasers and LED display devices based on II-VI semiconductors are among the brightest hopes of electro-optical research

Semiconductor lasers are among the most useful creations of solid-state physics. Compact and highly efficient, these minuscule marvels are the beacons that shine through long-distance optical fibers and the styli that read compact and other optical discs. Increasingly, they are critical components of high-speed data backplanes in computers, and before long, large arrays of them will be linking the machines over greater and greater distances.

If there is anything we would change about them, it is their wavelengths: we would make them shorter. The technological and commercial implications would be extraordinary: much greater data densities on the discs, to name just one. Some of the most intense and fascinating research in semiconductor technology concerns this very problem, and at long last, a solution seems within reach.

This bright development in electro-optics is due to a rapid succession of breakthroughs, each remarkable in its own right. One was the discovery, scarcely three years ago, that nitrogen could be used as the long-sought p-type dopant for the semiconductor materials viewed as the most likely emitters of blue light. Other advances included an improved understanding of quantum wells, and the application of epitaxial deposition techniques, particularly molecular beam epitaxy, to form extremely thin layers of different semiconductor materials. Finally, new materials engineering techniques have been developed to minimize misalignments at the interfaces of these thin, crystalline layers.

Using these techniques, our group, as well as researchers at 3M Co.'s research laboratories in St. Paul, Minn., recently fabricated semiconductor diodes that emitted pulses of coherent blue-green light at room temperature. These lasers have also been operated continuously at the liquid nitrogen temperature of 77 K, both by us and by other researchers in the United States and Japan [Fig. 1].

Robert L. Gunshor, Nobuo Otsuka Purdue University
Arto V. Nurmikko Brown University

For those in need of compact sources of coherent blue or blue-green light, this is good news indeed. There are already many obvious uses for such lasers. Besides the applications in data storage already mentioned, blue-light-emitting semiconductors could be used in bright, sharp red-green-blue display devices and in medical diagnostic systems.

In terms of the familiar compact-disc players, halving the wavelength by moving to the blue would instantly quadruple the data density that could be read by the system. Consequently, compact discs could either store more than 2600 megabytes rather than the current 650 MB, or disc size could be reduced significantly. Perhaps, too, digital image storage and playback could become an alternative to conventional photography.

Today, applications demanding blue or blue-green laser radiation can only be implemented with a gas laser. The commonest is the argon-ion laser. But its need for a power supply larger than a desktop computer rules it out wherever size, weight, or cost must be minimized—in compact-disc players, say.

TRUE BLUE QUEST. Why has a compact, low-cost source of coherent blue light proved so elusive? The answer lies in the physics of semiconductor laser diodes. These devices have the same elements as the much larger gas lasers—a region of optical gain where photons multiply and an optical wave propagates, and a feedback system to convert this photon amplifier into an optical oscillator.

> At last, a practical blue-green semiconductor laser may be at hand

A semiconductor diode is produced by joining two different materials, n-type and p-type, each created by doping the material with trace impurities. The n-type has an excess of electrons, whereas the p-type has a surfeit of holes. (Holes are vacancies in the electron population of the outer energy levels of the atoms making up the crystalline semiconductor.) Forward-biasing such a p-n junction greatly increases the number of electrons on the p side and holes on the n side, in effect forcing electrons and holes to meet and recombine. Under certain conditions, the energy of these recombinations is released as coherent light.

This phenomenon is responsible for the gain in a laser diode. The amount of energy released by a recombination—the energy of the photon emitted, in other words—is approximately equal to the bandgap energy of the semiconductor material at the point where recombination occurs. This bandgap energy is what carries an electron from the valence band (the energy of the electrons in the outer shell of an atom) to the conduction band, the next higher band of allowed energies. When radiative recombination occurs, an electron falls back into a vacant site in an atom's outer shell, and a photon is emitted.

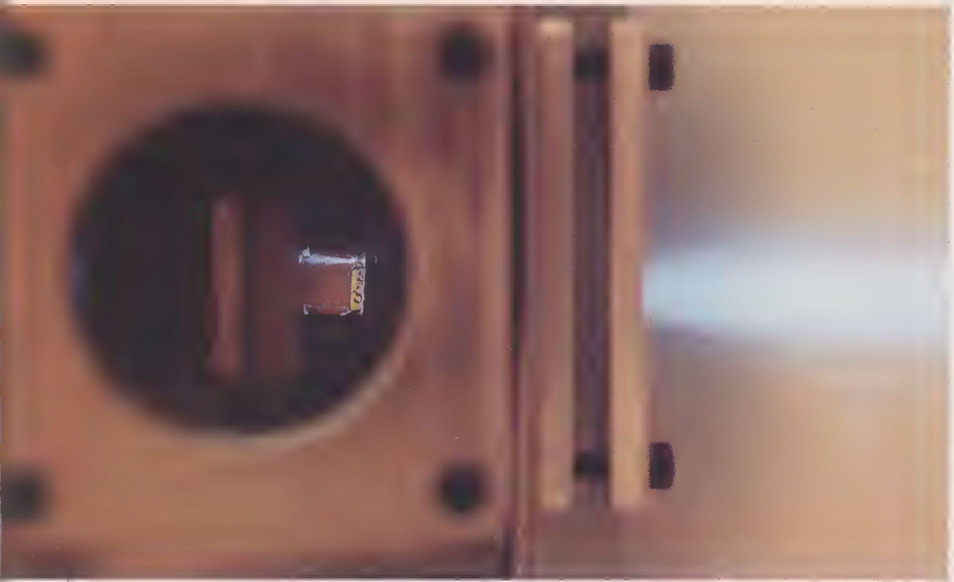
Today's crop of commercial semiconductor lasers is based on gallium arsenide (GaAs) and other compounds uniting chemical elements from columns III and V of the periodic table. These micro- to millimeter-sized devices emit coherent infrared or red wavelengths, and, as far as material and device technologies go, are quite mature. In p-n junction devices, their efficiency can exceed 50 percent, as measured by the conversion of electrons to monochromatic photons.

BIG BANDGAP. As for shorter-wavelength optical emitters, the prime candidates for at least 30 years have been the II-VI compound semiconductors, specifically those, such as zinc selenide (ZnSe) and zinc sulfide (ZnS), with relatively high bandgap energies, in excess of 2.5 eV. But they proved hard to make. It was difficult to control their electrical properties by selective impurity doping, and impossible to limit defects.

Further complicating the situation was the fact that not all the compounds of interest even possessed the same crystal structure, or phase. All practical laser devices are based on heterostructures, in which two different semiconductors meet one another in a single crystal at a boundary called a heterojunction. This boundary is crucial to the device's electro-optical properties, not least because differences in energy gaps along the boundary permit confinement of electrons and holes, while differences in the refractive index are exploited to guide the emitted light waves.

FABRICATION BREAKTHROUGH. Still, because of the frustrations endured with conventional crystal-growth methods, the II-VI materials in

0018-9235/93/$3.00©1993 IEEE



[1] In 1991, the first practical semiconductor lasers emitting blue light were demonstrated, this one by a team from Brown and Purdue Universities.

the early 1980s appeared fated to remain scientific curiosities. But in the last few years major new departures in the synthesis of these compounds and new ideas for heterostructure devices began reviving interest in the field.

Interest was further piqued by a proof-of-concept demonstration of blue-green diode lasers (and light-emitting diodes) in the summer of 1991. Working independently, a research group at 3M Corporate Laboratories in St. Paul, Minn., and a team from Brown and Purdue Universities achieved laser operation in ZnSe-based heterojunction diodes. Within the past year, another half a dozen groups located in Japan (Matsushita Electric Industrial, NTT, Sony), the United States (North Carolina State University, Raleigh; Philips Laboratories in Briarcliff Manor, N.Y.), and Scotland (Edinburgh's Herriott-Watt University) have also demonstrated diode laser action in this and related material configurations. By now, industrial laboratories around the world have stepped up or initiated work on wide-bandgap II-VI semiconductor devices.

During the early efforts to develop the II-VI technology, semiconductor crystal samples were usually grown in bulk. But these bulk-grown crystals generally suffered from too many defects, as well as heavy concentrations of background impurities. Roughly 10 years ago, therefore, an effort was made to develop nonequilibrium growth methods for the wide-bandgap II-VI materials. These new growth techniques were organometalic vapor phase epitaxy deposition (OMVPE), and molecular beam epitaxy (MBE). Although a few current II-VI efforts emphasize semiconductor crystal growth by OMVPE, the recent breakthroughs derive from MBE.

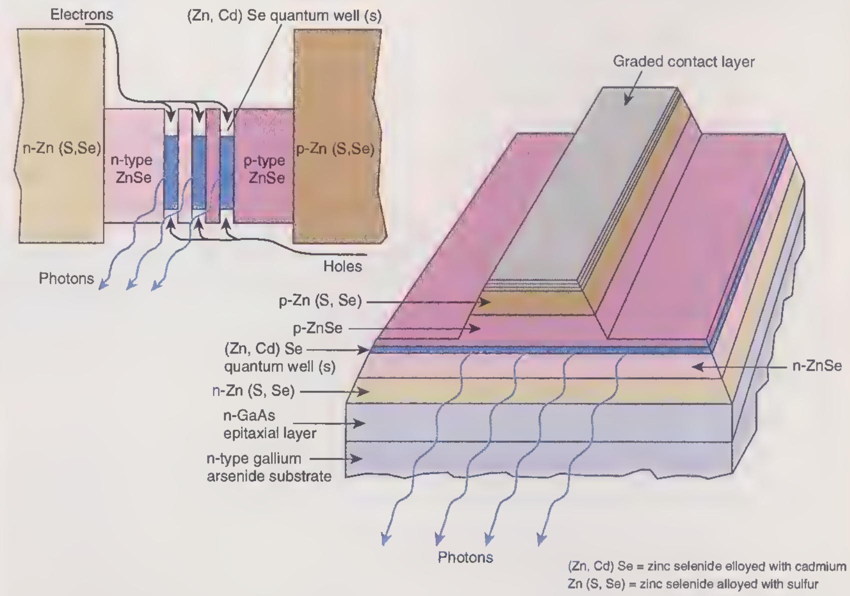
MBE makes use of a kind of elaborate evaporator in which an ultrahigh vacuum keeps stray impurities at bay as a semiconductor film is grown. The film's desired constituents are obtained from solid-source materials such as elemental zinc, selenium, and cadmium, which are placed in individual ovens and heated. The vapor emanating from each oven is controlled by a shutter; closing the Cd shutter results in the growth of ZnSe, while all three vapor sources would be used to grow crystals of the ternary alloy.

A crucial feature of MBE is that it can produce layered structures from several dissimilar semiconductor constituents, all adding to a "superlattice" composite and with thickness control on the scale of an individual atomic monolayer.

This ability to deposit thin layers is important. Narrow electron- and hole-confining layers, known as quantum wells, enhance the radiative recombination probability of the electrons and holes in a fundamental way due to the behavior of these particles when confined to the narrow space of these wells [Fig. 2]. In a laser diode, the well is positioned between the n- and p-type sides, and these confining barriers force electrons and holes together, speeding their radiative recombination. A device may have more than one quantum well, depending on a variety of design tradeoffs.

Quantum mechanical effects confer further advantages on the quantum well—an effective bandgap greater than that of the material from which it is formed, and a bandgap energy that increases as the well's width (typically 6–10 nm) is decreased. An additional requirement for an efficient laser diode is that the optical wave amplified in the gain region (quantum well) is itself also confined, by optical waveguiding, to the well region. This means the index of refraction must be higher for the well than for adjoining regions of the device.

In the blue-green diode lasers, the quantum wells are composed of a crystalline alloy consisting of mostly zinc selenide with cadmium atoms replacing zinc in random sites. This alloy, which is compactly written as (Zn,Cd) Se, has a narrower bandgap than the adjacent ZnSe or Zn(S,Se) barrier layers. The structure also serves an optical purpose: the cadmium-containing alloy embodying the quantum well has a larger index of refraction



[2] The salient features of the II-VI laser diode [above right] include a gallium arsenide substrate, through which electrons are introduced, and a graded contact layer, where holes are injected. The energy band diagram [above left] shows the various energy levels of the constitutent semiconductor materials in the diode. In the diagram, electrons tend to fall toward the bottom of the page, while holes tend to rise toward the top. They meet in the quantum well (of which typically there are one to six) to produce the coherent photons for lasing. The energy of the photon created is represented by the vertical height of the blue of the quantum well.

than the barrier layers, so the photons emitted by radiative recombination tend to be guided along the quantum well regions.

The ability of the (Zn,Cd)Se quantum well to confine holes and electrons—even at room temperature and beyond—is traceable to the conduction- and valence-band alignments (or rather misalignments) between the Cd-containing alloy and adjacent layers of ZnSe or Zn(S,Se).

All the blue-green laser devices reported to-date are grown on GaAs substrates, because large wafers of high-quality, single-crystal ZnSe are not yet available. Still, a fortuitous side effect of using GaAs substrates is that it enables these II-VI optical devices to be integrated with GaAs-based electronics.

One of the remaining materials engineering challenges is to minimize misfit dislocations, which form when crystals of different lattice dimensions are layered. Such dislocations are anathema to optical devices because they are potent nonradiative centers and increase the electrical resistance of the device; in the worst case, they can even cause a laser to fail completely. Methods of configuring laser and light-emitting diode structures so that integration with GaAs is achieved with a minimum of dislocations do, however, exist.

To summarize, the key components of most semiconductor lasers, whether a II-VI or III-V device, are an active quantum-well region, a p-n–junction heterostructure, electrical contacts to an external power supply, and the substrate/buffer layer on which the lasers are grown.

DOPING ISSUES. For both fundamental physical and practical reasons, the n-type doping of ZnSe is fairly easily accomplished, while p-type doping has historically presented a challenge. The first real candidate for the p-doping of ZnSe was lithium. Unfortunately, lithium threatened the stability of device structures because, as the second smallest atom in the periodic table, it diffuses all too readily in a host crystalline lattice.

In 1990 research groups led by Robert Park at the University of Florida, Gainesville, and Kazuhiro Ohkawa at Matsushita Electric Industrial Co.'s research laboratories in Osaka, were the first to succeed in p-doping ZnSe. Both groups used a nitrogen plasma source developed by Oxford Applied Research in Oxford, England, for application in high-vacuum systems; the growth technique employed was MBE. In fact, the nitrogen doping, presently reaching free hole concentrations of around 10^{18} per cubic centimeter, works for both ZnSe and the wider-gap alloy Zn(S,Se). Thanks to this doping breakthrough, useful II-VI p-n junction devices could at last be built. (Chlorine was the n-type dopant.)

QUANTUM WELL EFFECTS. Since about 1985, when optically pumped lasing of a ZnSe-based quantum well structure at 77 K was demonstrated at Purdue, research efforts have been focused on many different II-VI quantum well systems in hopes of discovering an electronically and optically optimal structure that would lead to a room temperature laser. Eventually, after systematic studies of the basic electronic and optical properties of numerous layered combinations, a potentially useful quantum well heterostructure emerged.

The MBE growth of the (Zn,Cd)Se/ZnSe quantum well configuration was first demonstrated by Nitin Samarth and Jacek Furdyna at the University of Notre Dame in Indiana, while experiments by the group at Brown University identified this system as a strong new candidate for useful confinement of elecrons and holes. This group employed optical absorption studies that showed how the confinement strongly enhanced the coupling between the electrons and holes in the (Zn,Cd)Se quantum well.

Fabrication of the blue light emitters had to await discovery of a practical p-doping technique

In most semiconductors, and especially the II-VI compounds, electrons and holes tend to pair off at low temperatures, forming a hydrogen-atom–like entity called an exciton, in which the electron orbits around the hole. This coupling increases the tendency for the two particles to recombine and emit a photon. An electron not coupled to a hole in this way is more likely to encounter a nonradiative recombination center; it will still return to the valence band, but the bandgap energy will be converted to heating the crystal instead of emitting a photon (thus degrading the overall efficiency of the semiconductor).

The (Zn,Cd)Se quantum wells enhance the electron-hole coupling of the exciton to such an extent that it can survive the thermal vibrations of the crystal lattice, even beyond room temperature. In previous wide-bandgap II-VI quantum wells, the excitons were dissociated well below room temperature, so that the chance of enhanced probabilities of radiative recombination was lost. But with the newer diodes based on (Zn,Cd)Se/ZnSe quantum well systems, laser operation at 77 K by optical pumping methods was demonstrated in 1990 at Brown, followed by pulsed room-temperature lasing a few months later.

One consequence of two-dimensional electronic confinement in a wide-bandgap II-VI semiconductor quantum well is that the electrostatic interaction between the electrons and holes becomes particularly potent, resulting in both increased exciton binding energy and increased probability for radiative recombination. At the same time, the ionic nature of the materials implies that, at other than cryogenic temperatures, the excitons may be pulled apart by the strong interaction of the lattice vibrations (specifically the "electrically active" longitudinal optical phonons). Provided that the quantum well confinement is strong enough, though, many excitons in a (Zn,Cd)Se quantum well can survive the thermal dissociation, and even dominate optical absorption and spontaneous emission (luminescence) right up to room temperature.

Recent spectroscopic work in our laboratories has suggested that the excitonic aspect also enters into the mechanism for gain in the blue-green laser diodes. In a conventional III-V laser diode, the gain is realized in the form of a degenerate (high-density) electron-hole plasma in which radiative recombination occurs to produce photons. In the case of GaAs, for example, the typical carrier density is high enough simply to screen the excitons out of existence. On the other hand, experiments on the (Zn,Cd)Se quantum well system indicate that, because of their greater robustness, the excitons contribute the most to optical gain at 77 K and may still do so to a significant extent at room temperature and beyond.

There is more than scientific interest in such a novel mechanism for semiconductor laser action. The exciton's inherently large oscillator strength can reduce the injection level necessary for laser operation well below that needed in the electron-hole plasma case.

INTEGRATED DESIGN. Like the longer-wavelength III-V diode lasers and LEDs, the II-VI light emitters are designed by closely interrelating electrical and optical considerations. Good electronic confinement improves the gain characteristics of the quantum well's injected 2-D electron-hole population, while reducing the leakage currents caused by carriers that manage to bypass the well. Equally important is optical confinement in a waveguide surrounding the quantum well so that the amplified optical electromagnetic field is perforce concentrated in the well, where the gain mechanism is centered.

In device fabrication, the ionic nature of ZnSe and its alloys lends them a brittleness that demands extra care in choosing processing techniques. While the detailed arrangements are part of ongoing research, each of these imposes special conditions on, and presents challenges to, the new devices.

Practical obstacles to realizing optimal designs for the active region in the blue-green laser diodes include: the difficulty of matching II-VI layers, both to each other and to the GaAs substrate; the rather small index of refraction contrasts (required for optical waveguiding) between constituent layers; and the need to adequately confine both holes and electrons in the quantum well.

Also, while the active hole concentrations achievable with p-type doping of ZnSe are reasonable, the mobilities of these holes within the semiconductor are distressingly

below theoretical predictions. Furthermore, heat generated by the diodes' relatively high resistivity remains troublesome. Another problem arising from the still imperfect electrical properties concerns the excessive operating voltages of 9–15 V.

To keep these difficulties in perspective, however, bear in mind that until 1990, there was almost no hard data on the transport of holes in p-ZnSe! Indeed, techniques reported last summer for forming ohmic contacts, described later, present the first opportunity for the systematic study and optimization of hole transport in ZnSe and related compounds.

INITIAL PERFORMANCE. The first laser diode heterostructures, fabricated in the summer of 1991, contained one or more quantum wells of (Zn,Cd)Se surrounded by barrier layers of ZnSe and/or Zn(S,Se). In these devices the group at 3M and the Brown-Purdue team obtained pulsed laser operation first at 77 K, and then at room temperature. The practicality of the device structures was made all the more likely when continuous-wave operation at 77 K was achieved by both 3M and the Brown/Purdue groups.

It was immediately apparent that the efficiency at which electrons and holes were converted into coherent blue-green light approached 100 percent at cryogenic temperatures, once the laser had reached its threshold. After discounting the finite reflection losses by the resonator end facets, necessary for obtaining useful output power from the device, the measured output characteristics implied that just about every electron-hole pair injected into the quantum well contributed usefully to the laser emission. This attested to the fundamentally robust stimulated emission mechanism that the presence of the quantum wells offers to the new light emitters.

Under pulsed conditions, room temperature operation was first realized with reflective end-facet coatings. Under such conditions, the current density at which lasing commences, known as the threshold current density, is approximately 1 kA/cm^2—in the range of representative values for III-V semiconductor lasers.

Threshold current densities on the order of 100–200 A/cm^2 have been routinely obtained at 77 K for the (Zn,Cd) Se/Zn(S,Se) and (Zn,Cd)Se/ZnSe/Zn (S,Se) heterostructure lasers. With typical cadmium concentrations of 10–20 percent in the active quantum wells, the emission wavelengths have been varied from 465–470 nm at cryogenic temperatures (blue) to 490–510 nm (blue/green) at room temperature.

EPITAXIAL FABRICATION. The epitaxial structures described here were grown and structurally characterized at Purdue University using a Perkin-Elmer MBE machine having separate growth chambers for II-VI and III-V materials. These chambers are connected by an ultrahigh-vacuum transfer system. The light-emitting devices employing these structures were constructed and evaluated at Brown University.

One of the most important aspects of device fabrication is minimizing mismatches at the boundaries between different crystalline semiconductors. Dislocations occur when the total strain energy in a thin semiconductor layer, or film, exceeds some threshold; the greater the mismatch between two lattices, the larger the strain as one layer tries to conform to the other. During film growth, the formation of misfit and threading dislocations arising from lattice constant mismatch to the GaAs substrate was minimized by growing the II-VI active region on an appropriate (In,Ga)As buffer layer and (in the case of the structures containing sulfur) by correct choice of the fraction of sulfur in the crystal.

The lattice mismatch strain in the heterostructure devices has a number of implications. First, the typical mismatch between (Zn,Cd)Se and ZnSe is of the order of 1 percent, while that between ZnSe and GaAs is about 0.25 percent. The former implies that only a few quantum wells (typically 7.5 nm thick) can be incorporated without exceeding the threshold for the formation of misfit dislocations.

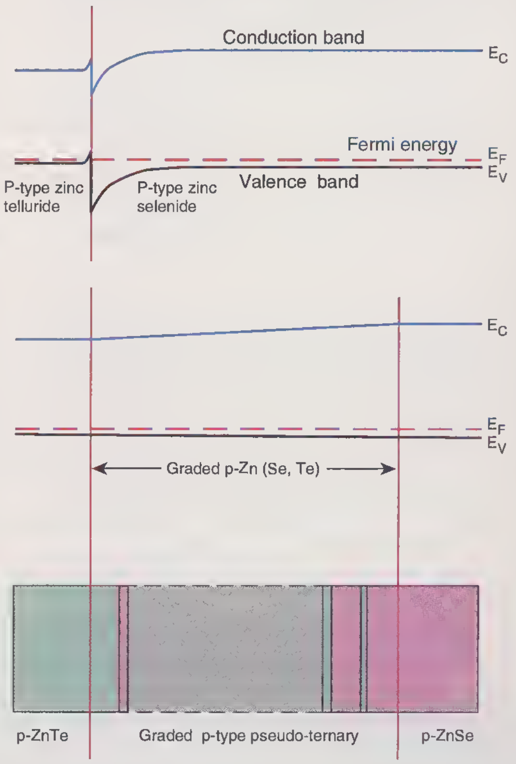
Furthermore, although the mismatch between the lattice constants of ZnSe and GaAs is a mere 0.25 percent, the critical thickness for a ZnSe layer grown on GaAs is only about 150 nm, while a typical laser diode structure would be 2 to 3 μm thick. In the absence of an effective scheme for matching lattice constants, the density of dislocations generated by mismatch during film growth would be high, easily above 10^8/cm^2.

Generally, the effectiveness of lattice matching, in this case to the GaAs substrate, is evaluated by measuring dislocation densities with X-ray diffraction and transmission electron microscopy (TEM). In the TEM evaluation of ZnSe-based devices employing the (In,Ga)As buffer layers, the dislocation densities estimated from the II-VI regions were found to be in the lower range of 10^6/cm^2, a value that can be reduced by further adjustment of the fraction of indium.

One method of evaluating the orderliness of the crystal lattice is measuring the narrowness of X-ray diffraction peaks when the source is "rocked" about the Bragg angle, one of the characteristic angles at which a crystal's atomic planes reflect X-rays. Dislocations due to lattice mismatch broaden these peaks quite effectively.

The Zn(S,Se)-based structures were grown with a sulfur fraction of approximately 7 percent, a value designed to lattice-match them to the GaAs buffer layer. The X-ray rocking curve diffraction peaks obtained from the Zn(S,Se) layers had full widths at half maxima of 20 to 65 arcseconds. That range indicates a high degree of order in the crystal, one commensurate with a very low density of misfit-induced dislocations. TEM imaging of our most recent devices indicates dislocation densities below 10^5/cm^2.

QUATERNARY EXPERIMENT. Another approach to boosting bandgap energy while curbing dislocations was revealed recently by researchers at Sony Corp. in Tokyo. Late in 1992, they reported the 77 K operation of a II-VI laser in which the electronic confinement in ZnSe quantum wells was provided by the use of the quaternary compound (Zn,Mg) (S,Se). The addition of magnesium increases the bandgap energy to values exceeding that of ZnSSe (of comparable sulfur concentration), while preserving a degree of lattice matching to the GaAs substrate. Because of the increased bandgap of the quaternary compound, cryogenic laser operation reached deeper into the blue (447 nm) than had



[3] The use of graded contact-layers to inject holes into II-VI laser diodes was pioneered in a joint Brown and Purdue University research effort. Gold, the traditional contact material, readily injects holes into zinc telluride (ZnTe), so the trick is moving the holes smoothly from the ZnTe to zinc selenide—from left to right in the above diagrams. The main obstacle to this is a heterojunction that forms where the two materials meet, where there is an offset between the valence-band energies of the two materials. Thus holes going from one material to the other must find their way over a valence-band barrier, or spike, caused by this offset [top]. However, discrete layers of ZnTe and zinc selenide (ZnSe) may be arranged as shown by at bottom, to approximate a uniform grading [middle] between the two materials' energy bandgaps.

been previously reported.

Perhaps more important, the use of the quaternary could open the way to a separate confinement heterostructure with improved optical confinement properties. Work is under way on these in several laboratories.

At Philips Laboratories, for example, researchers very recently showed that fabricating a separate confinement heterostructure with (Zn,Mg)(S,Se) as the outer optical and electronic cladding layers improves performance to the point where pulsed laser operation is possible well beyond room temperature. The Brown-Purdue group also recently used such a separate confinement heterostructure, incorporating magnesium, to demonstrate 1-μs pulsed laser diode operation with 0.1 percent duty cycle. This device had a lifetime exceeding a half hour at room temperature.

Given the rigid constraints imposed by lattice-matching difficulties within ZnSe and its ternaries, such as Zn(S,Se), significant materials research efforts focused on the quaternary materials seem inevitable.

ELECTRICAL CONTACTS. Clearly, many of the elements of a practical short wavelength laser or light-emitting diode are now in hand. However, it still needs a means to connect it to an external circuit. The ideal contact would provide a transition between the connecting wire and the semiconductor without producing a significant local resistance, or voltage drop, due to some barrier to the passage of charge. Such a contact is called a low-resistance ohmic contact.

When a metal is connected to a semiconductor, a parameter called the work function must be commensurate for the two materials; otherwise, the transition will impose a barrier to charge flow, called a Schottky barrier, across which there is an undesirable voltage drop. Until the past few months, no suitable metal having a sufficiently high work function to match p-type ZnSe had been found, so it has not been possible to form an ohmic contact.

Lacking such a capability, devices were in effect fabricated in two polarities: they were grown on n-GaAs substrates and their top p-type ZnSe layer had a gold Schottky contact deposited on it. In other devices, holes were injected from a p-GaAs substrate (despite the large valence band offset between GaAs and ZnSe), and indium was used to contact a highly doped n-ZnSe layer on top. Both schemes were used in operating diode lasers, but neither proved satisfactory for hole injection.

Despite the barrier to hole injection presented by the heterojunction between p-GaAs and p-ZnSe, this phenomenon has proved useful inasmuch as it spreads the current over distances of the order of a centimenter, which can be exploited for display devices. Thus it was found that the electrical contact to the top of a device need only be performed locally, yet light was emitted all over the (transparent) surface of the display device.

In one structure fabricated at Purdue, a transparent electrode material was employed to shift the top contact completely outside the active area in a seven-segment numeric display device. The programmable display emitted at 490 nm at room temperature with powers of up to 100 μW and a quantum efficiency nearing 0.1 percent [see "In search of the blue LED," below].

Until now, in fact, gold deposition has been the most widely used method for contacting p-ZnSe. But the Schottky barrier of the gold contact, though relatively low, obstructed the injection of holes from the connecting wire into the p-side of the junction. A remedy has been discovered at Purdue, where we took the recently discovered nitrogen approach for p-doping ZnSe and Zn(S,Se) and used it to implement doping levels in zinc telluride that are extremely high—above $10^{19}/cm^3$. The fact that gold makes a low-resistance contact to p-zinc telluride suggests the use of the heavily p-doped ZnTe as an intermediate layer for contacting p-ZnSe.

Another difficulty surfaces at this point—and another remedy. The valence-band energy-level offset at the heterojunction between ZnTe and ZnSe forms a significant barrier to hole injection [Fig. 3, top]. A possible means of eliminating this barrier is introducing a Zn(Se,Te) layer having a graded bandgap, where the grading has removed the valence band "spike" [Fig. 3, middle]. (A similar contact scheme, but employing a graded (In,Ga)As region, was previously employed by Woodall and colleagues at IBM's

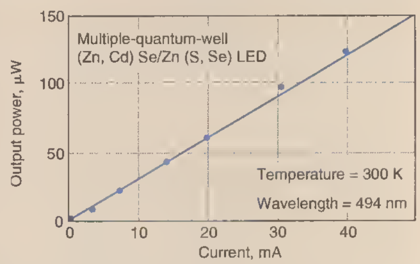
In search of the blue LED

Blue light-emitting diodes (LEDs) based on II-VI semiconductors are a useful and natural byproduct of the work on blue-green diode lasers. They, too, are also showing great promise for future optoelectronics applications.

One of the most developed is the zinc selenide semiconductor diode with a superthin light-radiating region, or quantum well. The well is composed of a crystalline alloy consisting of mostly zinc selenide with cadmium atoms replacing zinc in random sites; such an alloy is compactly written as (Zn,Cd)Se. While reading the performance discussion that follows, bear in mind that these II-VI LEDs, as constructed in the authors' laboratories, have not been optimized (optically packaged) to minimize internal reflections; they are simply samples that have a conducting dot on top for electrical contact.

At cryogenic temperatures, these diodes have excellent internal radiative efficiencies, with the conversion of electrons and holes into blue or blue-green light approaching 100 percent. Of course, not all of these photons actually escape from the device; hence a second measure of efficiency, which indicates the photon yield relative to injected electrons and holes, is actually a better indicator of how well the LEDs work. At room temperature, this external radiative efficiency reached in the authors' laboratories for (Zn,Cd)Se/Zn(S,Se) structures was typically about 0.1 percent. This much lower efficiency figure is partly due to the activity of nonradiative recombination centers, and partly to the total lack of optical optimization to enhance the transmission of photons from the material (which has a high index of refraction) to the air.

While this efficiency value is now limited, it compares favorably with the only relatively developed blue LED technology, which is based on the indirect bandgap silicon carbide. Recent advances in gallium nitride synthesis and preparation, especially in Japan, have also vastly improved the prospects for blue LEDs from III-V compounds.



At room temperature, the power output levels of a blue-light LED are quite respectable in comparison with other LED technologies.

The graph, based on work in our laboratories, shows the output power from a (Zn,Cd)Se/Zn(S,Se) quantum well structure at room temperature at the blue wavelength of 494 nm. The emission originates from an active material thickness of 45 nm. With graded bandgap Zn(SeTe) ohmic contacts, these LEDs can be operated at 5V rather than 9 or 12V, as with the evaporated gold contacts.

Novel concepts of bandstructure engineering have been used by the authors to vary the wavelength of the LED emission from the (Zn,Cd)Se

Thomas J. Watson Research Center in Yorktown Heights, N.Y., to inject electrons from a metal-InAs junction into n-GaAs.)

All is not quite resolved, though. In creating this graded bandgap by MBE growth, it is hard to control the tellurium fraction in the graded alloy region. The problem is that tellurium and selenium ions compete to react with zinc on the growth surface. As a way around this problem, a multilayer structure was grown in which the thicknesses of the ZnTe and ZnSe layers were varied to approximate a graded region [Fig. 3, bottom]. Whereas gold Schottky-barrier contacts would exhibit the nonlinear characteristics of a rectifying Schottky contact, the graded contact structure appears to be perfectly ohmic, showing a straight line through the origin of a plot of current versus voltage.

An alternative approach to the contact problem involves mercury selenide. A group at North Carolina State University recently used MBE to introduce the compound between the metal and ZnSe as a means of forming an improved contact to p-ZnSe.

FUTURE DIRECTIONS. At this point, diode laser and LED operation in the blue and green has been obtained from a variety of MBE-grown II-VI heterostructure devices. Continuous operation has been widely demonstrated at 77 K, while three groups have achieved pulsed operation at room temperature. In particular, Philips Laboratories and the Brown-Purdue group both recently demonstrated relatively robust pulsed laser operation at room temperature and above with separate confinement heterostructure configurations of the quaternary compound (Zn,Mg)(S,Se)—strong evidence that these materials may be the key to achieving continuous operation at room temperature.

Clearly, wide bandgap II-VI semiconductors have established their place among photonic devices. Nevertheless, a good many materials-related questions remain. What combinations of materials will prove best for widening the available spectrum to cover the green and near-UV portions? What factors limit device lifetime in this materials system? What problems will be associated with manufacturing II-VI devices?

Areas ripe for future development include the optimization of growth techniques, to create fewer point defects that degrade quantum efficiency and raise threshold currents at room temperature. More work is also needed in optimizing the free hole concentrations and reducing the resistivity of the p-doped epilayers. (Increased hole concentrations should also lower the contact resistance further.)

At the same time, there is on-going exploration of additional laser geometries, including ideas for surface emitters. Several display device efforts are also under way, again in the direction of extending the available wavelengths.

TO PROBE FURTHER. The growth issues for the wide-bandgap II-VI compounds are reviewed in a chapter by R.L. Gunshor, L.A. Kolodziejski, A.V. Nurmikko, and N. Otsuka titled "Molecular Beam Epitaxy of II-VI Semiconductor Microstructures" in Volume 33 of the series *Semiconductors and Semimetals* (T.T. Pearsall, ed.). The series was published by Academic Press, San Diego, in 1991.

For more on the most effective quantum well configuration for the new light emitting devices, see the article by N.T. Pelekanos and A. V. Nurmikko, among others, in the Feb. 15, 1992, *Physical Review B*. The role of excitons in lasers is discussed in *Physical Review Letters*, 1992, Vol. 69, p. 1707.

The first reports of compact blue-green laser diodes appeared in 1991 in articles by the 3M Co. and Brown-Purdue groups: M. Haase, J. Qiu, J. DePuydt, and H. Cheng, in *Applied Physics Letters*, Vol. 59, p. 1272; and H. Jeon, with eight others, including A.V. Nurmikko and R.L. Gunshor, in *Applied Physics Letters*, Vol. 59, p. 3619.

The first reports of successful p-doping of ZnSe using the nitrogen plasma cell are to be found in a 1990 article by R.M. Park and others in *Applied Physics Letters*, Vol. 57, p. 2127, and in a 1991 paper by K. Ohkawa and others, in the *Japanese Journal of Applied Physics*, Vol. 30, Part 2, Letters, p.52.

Techniques for forming ohmic contacts to p-ZnSe are discussed in Vol. 61 of *Applied Physics Letters* by Y. Fan and nine others (including this article's authors) in a paper beginning on p. 3160, and by Z. Yang and others in a paper starting on p. 2671.

ABOUT THE AUTHORS. Robert L. Gunshor (F) is the Thomas Duncan distinguished professor of microelectronics at Purdue University in West Lafayette, Ind. Since 1983 he has been involved in the growth and optical, electrical, and microstructural characterization of a wide range of II-VI and II-VI/III-V semiconductors. He is a fellow of the American Physical Society and a member of the Materials Research Society.

Arto V. Nurmikko (M) is professor of engineering and physics and director of the Center for Advanced Materials Research at Brown University in Providence, R.I. Earlier in his career he led a team that developed means to use optically induced changes in semiconductors to switch long-wavelength infrared radiation at picosecond speeds. He is a Fellow of the American Physical Society and was the recipient last year of a Guggenheim Fellowship.

Nobuo Otsuka is professor of materials engineering at Purdue. His current research areas include high-resolution transmission electron microscopy of epitaxial interfaces and the growth kinetics of molecular beam epitaxy. He is a member of the Materials Research Society and the American Physical Society.

The research described here was supported by the University Research Initiative of the U.S. Advanced Research Projects Agency and Office of Naval Research, the Air Force Office of Scientific Research, and the National Science Foundation. ◆

quantum wells by the incorporation of tellurium as an isoelectronic center. All this means is that the incorporated impurity, in this case tellurium, shares the same VI column of the periodic table with selenium and thus has the same chemical valence. The physical properties of an isoelectronic center in ionic materials such as (Zn,Cd)Se include a high degree of local crystal lattice distortion when a hole (or an exciton) is trapped at the site.

The reduction in energy associated with the localized lattice distortion implies substantial "red" shifts in the ensuing spontaneous emission, depending on the details of the dosage of tellurium incorporated in the material. Thus by adding ultrathin sheets of tellurium during molecular beam epitaxy into the (Zn,Cd)Se quantum wells, the authors have been able to shift the LED emission wavelength from the blue into the green and yellow-green (below).

This is a rather large spectral range for a minor modification of the underlying material composition, and it suggests that it might be possible to build integrated multicolor LED emitters based on the II-VI semiconductors. A further possibility would be full-color LED display screens based on this basic technology. —*R.L.G., A.V.N., N.O.*

IEEE SPECTRUM

FOCUS REPORT AND GUIDE TO

ENGINEERING WORKSTATIONS AND PCs

ALSO COVERING: SERVERS ■ X TERMINALS ■ DSP BOARDS ■ STORAGE AND BACK-UP SYSTEMS ■ MULTIMEDIA ■ GRAPHICS DISPLAYS ■ AND MORE

NEW! HOW ENGINEERS USE PCs

FOCUS REPORT AND GUIDE TO

ENGINEERING WORKSTATIONS AND PCs

Network Computing Devices Inc.

Silicon Graphics Inc.

In the year since *IEEE Spectrum* last looked at the field in depth, the world of workstations and personal computers has seen a lot of activity...and as we go to press, the battle to beat the competition with better performance at a lower price has not let up.

The industry has been debating for the last few years whether the PC and the workstation have been chasing separate engineering markets or basically the same one. In *Spectrum*'s definition, the word "workstation" has been employed as a blanket term to cover systems ranging from high-end personal computers to high-end RISC machines, because readers use both for their work. This year, readers were surveyed to find out just how they are using Apple and PC-compatible computers and in what areas personal computers have an edge over workstations. The survey report is followed by a sampling of the latest high-end PCs.

With all the new offerings in workstations, potential purchasers need some rational way of comparing actual performance. Joshua Mogal of Silicon Graphics Inc., Mountain View, Calif., describes various types of benchmarks (software that checks some aspect of system performance), how they work, and what they say about system performance. A table presents the latest workstations grouped by price range.

But PCs and workstations alone will not provide the best of all possible computing environments. An essential element in optimizing system usage is the X terminal—a terminal designed to work with a network of distributed computing power. In a brief article and table, *Spectrum* scans some of the newest color and monochrome units.

The ultimate system optimization may require an extremely powerful computer as a resource that can be widely shared among many lesser machines. In their article, Mark Furtney of Cray Research Inc., Eagan, Minn., and George Taylor of Sun Microsystems Inc., Mountain View, Calif., give readers some guidelines for figuring out just how much computing power should be in workstations and in servers. Some recent servers appear in the accompanying table.

Tailoring workstations and PCs to fit the job at hand has never been more possible, thanks to the wealth of peripherals and add-on boards available to engineers today. To round off this report, Contributing Editor John King reviews the latest ways of souping up a computer.

Richard Comerford Senior Editor

Photo credits for p. 35 from left to right: top row: Hewlett-Packard Co., IBM Corp., Mobius Computer Corp. Middle row: Network Computing Devices Inc., RDI Computer Corp. Bottom row: Silicon Graphics Inc., Sun Microsystems Inc., Tatung Science & Technology Inc.

Defining terms

Cache: a high-speed memory that resides logically between a central processing unit (CPU) and main memory, and holds data and/or instructions the CPU is most likely to need soon.

Complex-instruction-set computer (CISC): a traditional computer with complex addressing modes whose CPU is designed to run many, often lengthy built-in instructions that support high-level languages. (See also reduced–instruction-set computer.)

Distributed Computing Environment (DCE): a set of requirements and applications developed by the Open Software Foundation as an infrastructure for systems heterogenous, networked computers.

Extended Industry Standard Architecture (EISA): an extension of the ISA bus that provides systems based on 80386 and later processors with compatibility with earlier ISA systems.

Fiber Distributed Data Interface (FDDI): a network based on the use of optical-fiber cable to transmit data in non–return-to-zero, invert-on-1s (NRZI) format at speeds of up to 100 megabits per second.

Gouraud shading: in computer graphics, a method of shading a polygon to produce a seemingly three-dimensional object with a matte surface.

Industry Standard Architecture (ISA): the name given to the bus architecture developed by IBM Corp. for the AT version of its personal computer. (See also Extended Industry Standard Architecture.)

Massively parallel processing (MPP): a computer architecture in which hundreds or thousands of closely coupled scalar microprocessors work in tandem.

Mflops: millions of floating-point operations per second.

MicroChannel Architecture (MCA): a proprietary architecture used by IBM Corp. for 80386 and higher processors.

Multichip module (MCM): a small package containing ICs bonded directly to a special substrate that allows high-speed transmission.

Open Systems Interconnection (OSI): a widely adopted model for a computer network architecture promulgated by the International Organization for Standardization that divides network functions into seven layers.

Parallel vector processing: an architecture in which several vector processing systems, which use multiple accessing of interleaved memory, can work in tandem.

Phong lighting: in computer graphics, a method of rendering a polygon so as to produce the effect of specular reflection from its surface.

Physical address: a binary address that refers to the actual location of information stored in a second level of memory, for instance, a disk drive.

Reduced–instruction-set computer (RISC): an extremely regular, easily pipelined computer in which the instruction set is simplified and minimized.

Server: a computer that provides a network with a specified service, such as data storage and retrieval or high-speed computing.

Small Computer Systems Interface (SCSI): an industry-standard high-speed interface for second-level storage systems.

SPECmarks: a normalized measure of performance for RISC systems based on a standard set of operations.

Thick Ethernet (10base5): an Ethernet in which the physical medium is a doubly shielded, 50-ohm coaxial cable capable of carrying data at 10 Mb/s for a length of 500 meters (often referred to as thicknet).

Thin Ethernet (10base2): an Ethernet in which the physical medium is a single-shielded, 50-Ω RG58A/U coaxial cable capable of carrying data at 10 Mb/s for 185 meters (often referred to as cheapernet or thinnet).

Twisted-pair Ethernet (10baseT): an Ethernet in which the physical medium is an unshielded twisted pair capable of carrying data at 10 Mb/s for a maximum distance of 185 meters.

Transputer: a microprocessor having internal RAM and communication links to other transputers, an arrangement that facilitates the design of parallel-processing computers.

VESA local bus (VL bus): a standard interconnection defined by the Video Electronics Standards Association for transferring video information to a computer display system.

Virtual address: a binary address issued by a CPU that indirectly refers to the location of information in primary memory, such as main memory. When data is copied from disk to main memory, the physical address (which see) is changed to the virtual address.

Engineers and PCs

A survey shows that most Spectrum *engineers are fans of high-end personal computers, but more for business than for engineering*

To see what role IBM-compatible and Macintosh computers play in the daily lives of its readers, *IEEE Spectrum* in February conducted an in-depth survey. The responses when tabulated reveal that our readers are an extremely PC-literate audience, using machines both at home and at work. And in both places, readers are using their PCs more for business than for engineering work. [For details on how the survey was conducted, see "Number, theory...and practice," at right.]

What kind of jobs did respondents have? About 45 percent were in management. While 9 percent were in general or corporate management, the majority were engineering managers or project leaders/engineers. About 20 percent of the respondents were involved with R&D or design and development, either as managers or hands-on engineers.

With 920 of the survey's respondents—almost all or 96.5 percent—stating they use personal computers [Fig. 1], it is safe to surmise that the technical community has broadly adopted them. Also, roughly 70 percent of the respondents like having their PCs close by—they have units both at home and at work. The majority of PC users (82 percent) are working with IBM-compatible PCs, while the remainder are using Apple Computer PCs. And a sizable percentage are doing double duty—29.1 percent of those who use PCs at work also use a workstation there.

Interconnection fever has also seized most users. Two out of three respondents who use PCs at work have them connected to a network, and 90 percent of those networks have file servers. Half of the at-work PC users have modems, while two out of three at-home PC users have modems. Among those who do not, two out of five plan to buy one in the next year.

When it comes to PCs, *Spectrum*'s readers are not neophytes. About one in four was using a PC 10 or more years ago, and over half have been using them for seven years or longer; the median for the entire group was 7.7 years. Furthermore, there is about a 50-50 chance that they are using more than one PC at work.

At home, on the other hand, only one in four is using more than one PC [Fig. 2]. Just about everyone uses a desktop system, but about one in 10 is using a laptop or notebook system, too [Fig. 3].

While nine out of 10 of the survey's respondents have company-supplied PCs at work, three-fourths of the home PCs were privately purchased. Their companies are now spending US $2000–$2999 for each office computer, and of the 20 percent of respondents who are planning to buy a PC for home use in the next year, most expect to spend that much.

At the office, 66 percent of the respondents say their company definitely plans to buy PCs in the next 12 months, while about 20 percent are uncertain of their company's plans. So more than eight in 10 of the respondents are potential PC purchasers in the coming year. Among those who are involved in the purchase of PCs for work, the most important issue in making a selection is the reliability of the system; over 68 percent rated it very important.

At work, the most-used brand of PC is IBM, according to our survey; 20.5 percent of the respondents who used PCs at work said they had the Armonk, N.Y., firm's machines. The second most popular at-work brand, with a response of 17.6 percent, was Apple. The only other double-digit percentage for an at-work brand was Compaq Computer Corp. with a response of 10.4 percent, and the category "Other" received more mentions than Compaq, with a response of 12.3 percent.

In answer to a question about what brand of PC was used at home, respondents listed "Other" most of all the categories (21 percent). Second, with a 17.2 percent response, was Apple, followed by IBM with 13.3 percent. No other single brand was identified by more than 7 percent of the respondents. Those who used Apple machines at work were most likely to use that brand at home, too.

More than half of those involved in purchasing a PC rated

Richard Comerford Senior Editor

Number, theory...and practice

At *IEEE Spectrum*'s request, an independent market research firm surveyed the magazine's readers and analyzed their returns. Those surveyed were selected by first choosing several thousand names at random from *Spectrum*'s U.S. mailing list. (This process is referred to as "sampling on an Nth name basis" in market research circles.)

Addresses outside the United States were not used because of the extremely long waiting times overseas mailings typically require. That was also the reason why any APO/FPO addressees were eliminated. Thus, survey data reflects the PC usage habits of individuals in the United States only.

In addition, the actual work sites were not known to the surveyors. Finally, the sample was filtered to eliminate the names of libraries, institutions, students, and those who are retired, because the objective was to determine how working individuals were using personal computers.

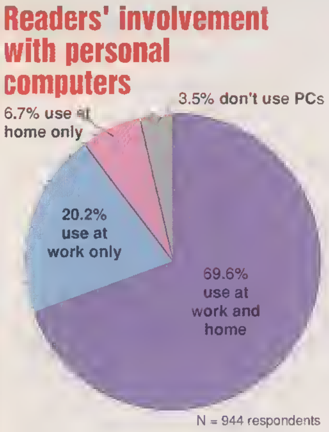
The sample selection processes yielded 2000 people, to whom postcards were mailed alerting them that they had been chosen for the survey. The post office was unable to deliver nine of these cards, thereby reducing the actual sample size to 1991 individuals. This group was then sent a letter identifying *Spectrum* as the publication conducting the survey along with a survey questionnaire with 54 questions, plus a cash incentive of US $1. So as not to skew results, the survey stressed that even those not using a personal computer should answer the questions that applied to them. The survey forms were mailed on Feb. 17 and results were based on returns received by March 8.

By that date, 944 people, or 47.4 percent of the sample, had sent in completed questionnaires. Analysis of the respondents' answers to type-of-work and work-location questions showed that the sample reflected the readership of *Spectrum*.

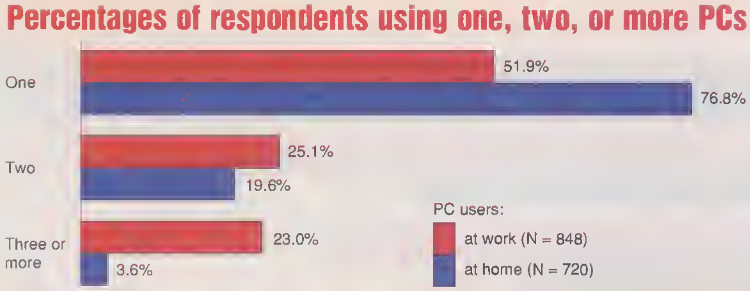
Two and a half weeks is a relatively short time for a survey. Typically, a survey will be left "in the field" for five weeks or more, reflecting conditions over a longer period of time. That extended timeframe may also increase the response somewhat and thus potentially reduce the margin of error. Had the analysis been performed after five weeks, the margin of error would have been based on a response rate of 53 percent.

With the 47.4 percent response rate used, the cumulative data is accurate within plus or minus 3.1 percent at a 95-percent confidence level. That means that, were data taken across the entire population in samples of the same size, 95 percent of the samples would produce results within the stated accuracy range. It is therefore possible to project the survey results obtained across the entire population of North American members of the IEEE. —*R.C.*

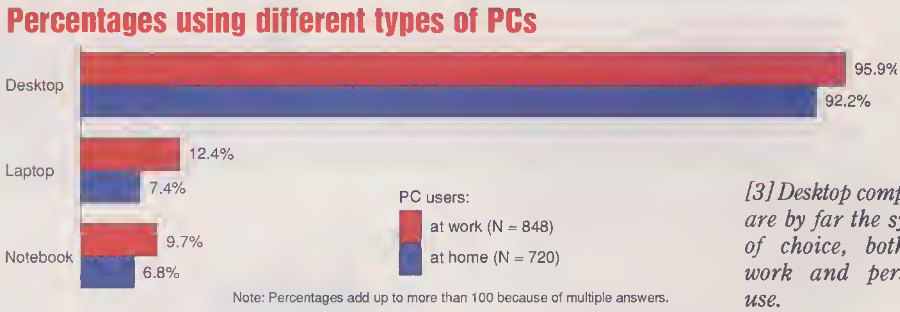
0018-9235/93/$3.00©1993 IEEE



[1] The vast majority of Spectrum's *readers are users of personal computers.*



[2] A little less than half of those surveyed who use PCs at work use more than one.



[3] Desktop computers are by far the system of choice, both for work and personal use.

the purchase price, the operating system, and compatibility with existing systems as being important features to study before deciding what to buy. Differences in ratings among these three factors were within the margin of error for the survey, suggesting that respondents viewed them as being equally important. Rated relatively unimportant were physical characteristics like size and weight, according to over half (52 percent) of the respondents who use PCs at work.

As might be expected, more of the purchasers of PCs for work deal directly with the manufacturer's sales force than with any other group (34.2 percent). But 31.5 percent buy from computer stores, 23.7 percent go to business/office equipment dealers, and 19 percent are purchased through direct response marketing (mail or telephone) or from catalogs.

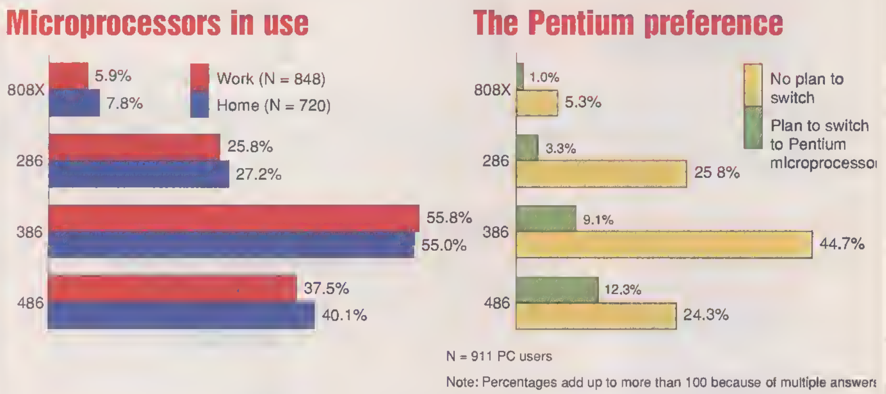
Home improvements are also keeping users active. Almost two out of every five of those who use PCs at home have bought a new one in the past, and about 60 percent have upgraded their systems with add-on enhancements—on the average, 1.7 times. Of those planning to buy new machines in the next 12 months, 31 percent will do so through direct response or catalog sales, 26 percent from computer stores, and 19 percent from the manufacturer's sales force.

Considering that one can get a 33-MHz, 386-based PC with VGA color monitor and 80-MB hard drive for under $1000, why would users spend as much as $2000–$2999 for a new machine. The answer is that those who are moving up are likely to be buying an advanced system, one based on a 486 or higher chip. Over half the respondents currently use a 386 system at work or at home, and one in three already uses a 486 system. Not surprisingly, one in three 486 users plans to move to Intel Corp.'s Pentium microprocessor in the next 12 months, as systems based on it start coming to market. Furthermore, about 20 percent of the 386 users do, too [Fig. 4].

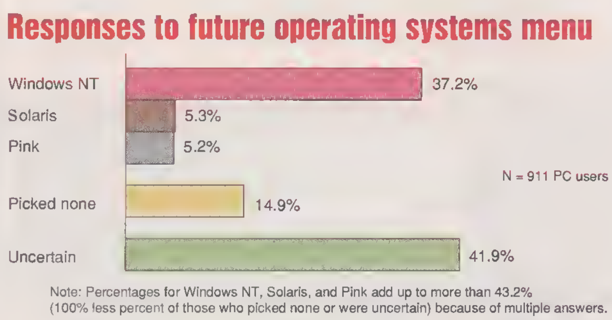
In addition to having a high-end processor, the respondents are likely to have state-of-the-art displays. At present, almost 89 percent of those who use PCs at work have a color monitor, as do 77 percent of those who use a PC at home. About half of both groups have above-average resolution displays: Super VGA, XGA, or higher.

But using PCs for multimedia applications has not yet caught on with most readers. Only about one in 10 PCs is currently outfitted with a compact-disc ROM, and is being used at work and at home for multimedia work.

Among those who do not now have multimedia capability at work, only 7.4 percent planned to add such capability in the next 12 months. However, with 34 percent of at-work users uncertain about adding it, the

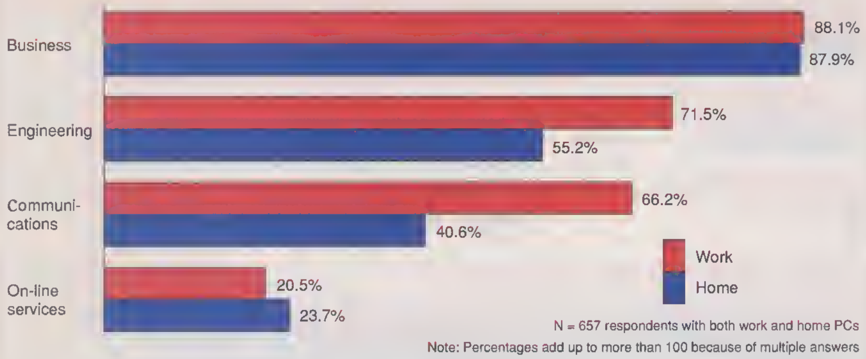


[4] More than half of the IBM-compatible PC users responding to the survey were already using a 386 or 486 system. That group is the most likely to switch to Intel's Pentium chip when it is available.



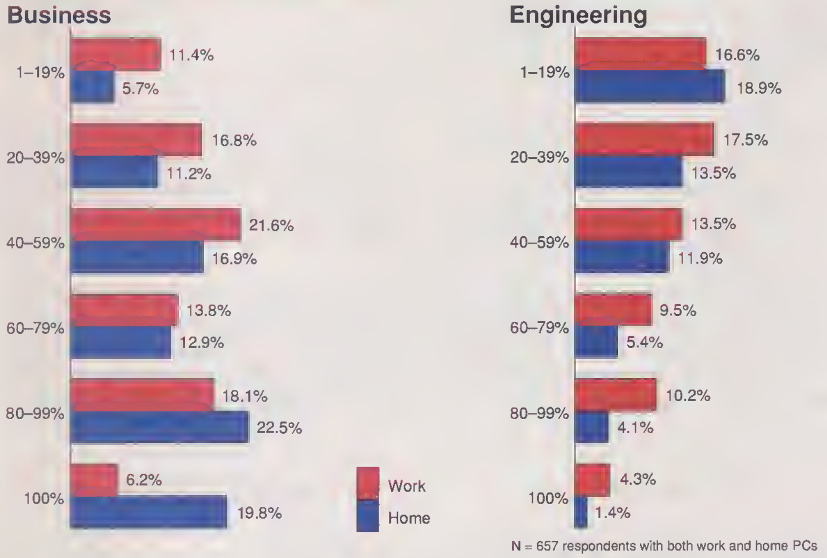
[5] There is a clear enthusiasm for Windows NT among Spectrum's *readers, but as yet it does not have a lock on everyone's imagination, as the number of those who indicated their uncertainty shows.*

Functions for which PCs are used



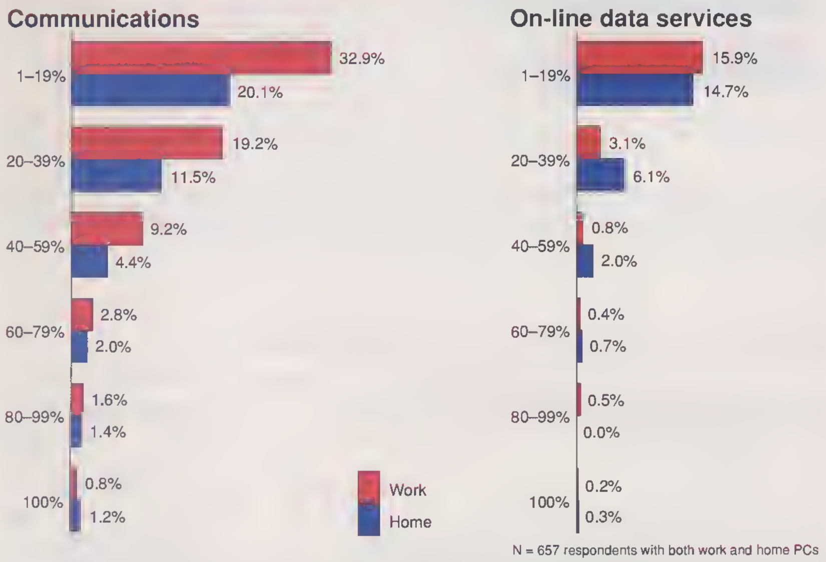
[6] The almost 90 percent of respondents with PCs both at home and at work claim that they use the PC for business functions. Engineering and communication also rank high.

Proportion of PC time spent on:



[7] Business functions are not only the most common use for PCs, both at work and at home, but users spend a great deal of time at it; more than half spend over half their PC time at work handling business matters. Engineering tasks do not absorb nearly as much time.

Proportion of PC time spent on:



[8] The PC is certainly a communication tool for a good many respondents, but little time is spent on that activity; the largest single group spends less than 2 in 10 minutes on communication. On-line services are slightly more likely to be used at home than at work.

size of the technical multimedia market this year will depend on how successful manufacturers are in convincing potential users that the technology has practical merit. And more than half the group said that they would not be using multimedia in the next year.

For the home market, the picture is a little brighter. Almost twice as many at-home users (13.7 percent) plan to add multimedia functions during the year. Still, 36 percent of home users have not yet made up their minds.

The operating system of choice, of course, tracks with the kind of PC used. Those using IBM-compatible PCs for the most part use DOS/Windows, while Macintosh owners use a Mac OS. Only about 5 percent of respondents were using OS/2 at work and less than half of that total used it at home. About 7 percent of respondents were using some form of Unix at work, with Mac users slightly more likely (12 percent) to be using Unix than IBM-compatible PC users.

The choice of future operating systems, however, is not so clear. Those surveyed were asked, "Which of the following operating systems would you seriously consider using, assuming that all will be available in the near future?" The choices were: Solaris for the PC, Windows NT, Taligent ("Pink"), None of the above, and Don't know.

The answers received showed that operating system battles are far from over at the PC level. Among the operating system choices, Windows NT was the only one that was a serious consideration, with a response rate of 37.2 percent [Fig. 5]. But a larger number of readers (41.9 percent) are undecided about what operating system is in their future, and 14.9 percent plan to use none of the systems mentioned.

PC WORK. What are users doing with all these PCs? To examine PC usage at home and at work, the survey tracked the habits of that group of respondents who use PCs in both places (657 respondents in all).

For the vast majority, the answer was for taking care of business. Regardless of where they use their PCs, they use them as business tools. That is the claim of 88 percent of those respondents who have PCs in both places [Fig. 6].

The pattern of usage, in terms of the amount of time spent, seems to vary a lot. At work, a user will spend about 48 percent of his or her time at the PC, on the average, performing business (as opposed to engineering) functions. At home, the user is likely to spend even more time on business tasks than at work; on the average, 64 percent of time spent at the home PC is on business operations.

Among those who have PCs both at work and at home, fewer use the PC for engineering work than for business. More engineering work is done on PCs at the office by respondents (71.5 percent) than at home

High-end PCs (Mac or IBM-compatible): a representative sample of those available

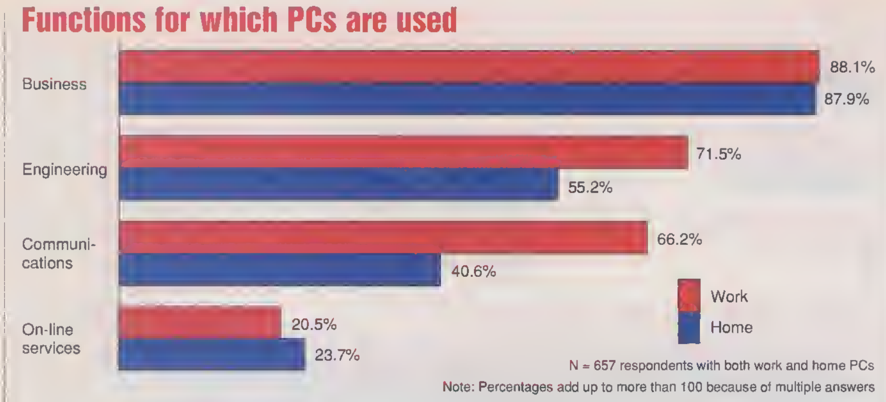
Performance ratings[1]	Central processing unit	Operating systems[2]	Memory[2]	Mass storage[2, 3]	Monitor[2]	Interfaces[2, 4]	Other features and options[4, 5]
Apple Computer Inc., Macintosh Quadra 950, $6099–$8149							
N.A.	Motorola 68040—33 MHz	System 7.1	Cache: internal, 8 KB RAM: 8 MB (256 MB), 80 ns	Internal, 500 MB (1000 MB)	(Monitor is optional)	E, SCSI, 2 serial,video, sound input	Stereo output from mono input; up to four 5.25-inch half-height storage devices may be installed; A/UX configuration also available
CompuAdd Computer Corp., CompuAdd 466 Desktop Power, $2609–$9876, varies							
MIPS : 26.3; Landmark: 222.9; Norton 5.0: 127.8	Intel i486 DX2/66	MS DOS 5.0, MS Windows 3.1 (Interactive Systems Unix, OS/2 2.0)	Cache: internal, 8 KB; external, 64 KB (256 KB) RAM: 4 MB (64 MB), 80 ns	Internal, 80 MB (1 GB)	Color, 14-inch, 640 x 480 pixels (color, 14-inch, 1024 x 768, or 15-, 16-, 17-, or 20-inch, 1280 x 1024)	C, 2 serial (E, TR, ISDN SCSI, SCSI 2)	Upgradable with future Intel OverDrive processors based on Pentium architecture; flash BIOS for updating via software
Dell Computer Corp., Dell 450ME, $2799–$6710, 5 work days							
N.A.	N.A.	MS DOS 5.0, MS Windows 3.1 (Unix SVR4, OS/2 1.21)	Cache: internal, 8 KB; external, 128 KB RAM: 4–64 MB, 70 ns	Internal, 80 MB (1.4 GB)	Color, 14-inch, 1024 x 768	C (E, TR, SCSI 2)	—
Dolch Computer Systems, CPAC 486-66C, $7498–$20 262, 2 weeks							
MIPS : 27.5	Intel i486	(MS DOS 5.0				232C SCSI	E, TR, and ISDN available from third parties
						R)	Options include 18-by-13-inch digitizer with stylus ($995); second color monitor, 17- or 19-inch ($1500–$1900)
						R, SCSI,	Fax/modem optional; VESA local-bus graphics standard
						R, CSI 2)	Multimedia kits and IDE caching and non-caching; VESA local bus; tower case option

ntinued on following page)

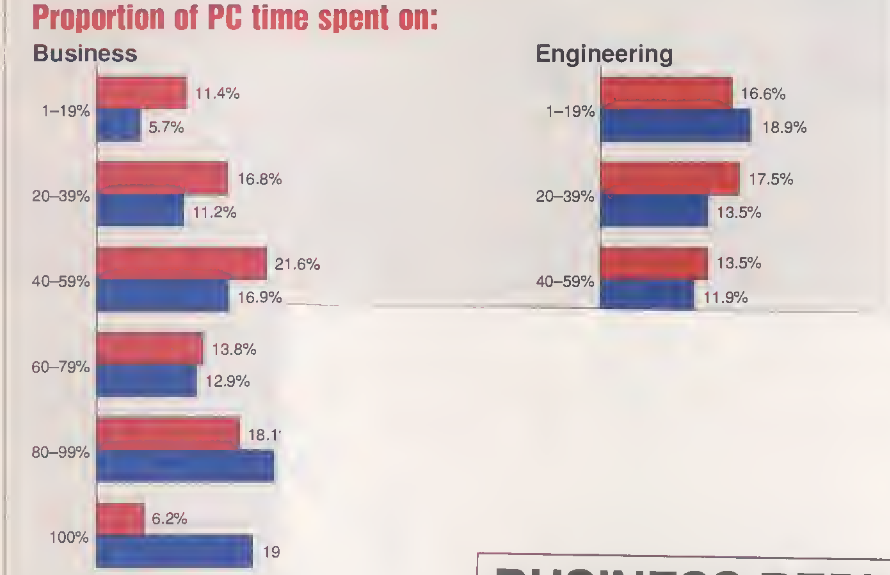
As previously noted, about two-thirds of PC users at work are connected to networks and about half have modems. Not surprisingly then, about two-thirds spend some time communicating at their workplace. They do not, however, spend much time using their PCs to communicate; on the average, only 16 percent do. At work, even less time is spent using on-line data services.

work to perform engineering and communication functions are probably using a workstation for those tasks. A total of 208 respondents (31.7 percent) have a workstation at work, as well as a PC at home and at work. Of that group, 131, or 63 percent, noted that the work they do on their PC is completely separate and distinct from the work they do on their workstations. On the

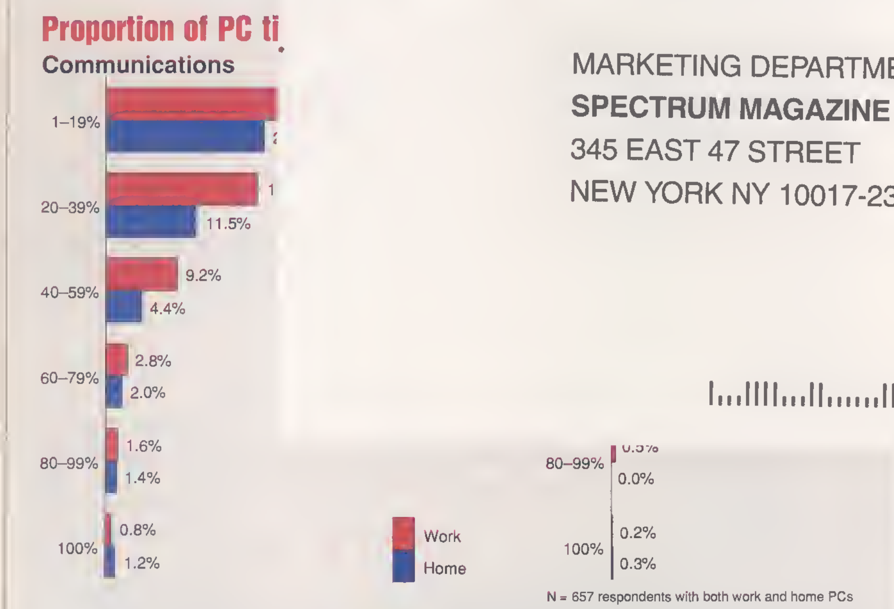
y about 4 percent of re- a workstation at home. oximately two-thirds of the respondents have modems in their home computers, they do not spend much time communicating with others or with their computer at work. About 41 percent use their home computers for communication functions and only 23.7 percent use them to access on-line data services. On the average, they use their at-home PCs less for communications, but slightly more to access on-line data services. ◆



[6] The almost 90 percent of respondents with PCs both at home and at work claim that they use the PC for business functions. Engineering and communication also rank high.



[7] Business functions are ... but users spend a great de... work handling business m...



[8] The PC is certainly a communication tool for a good many respondents, but little time is spent on that activity; the largest single group spends less than 2 in 10 minutes on communication. On-line services are slightly more likely to be used at home than at work.

size of the technical multimedia market this year will depend on how successful manufacturers are in convincing potential users that the technology has practical merit. And more than half the group said that they would not be using multimedia in the next year.

For the home market, the picture is a little brighter. Almost twice as many at-home users (13.7 percent) plan to add multimedia functions during the year. Still, 36 percent of home users have not yet made up their minds.

The operating system of choice, of course, tracks with the kind of PC used. Those using IBM-compatible PCs for the most part use DOS/Windows, while Macintosh owners use a Mac OS. Only about 5 percent of respondents were using OS/2 at work and less than half of that total used it at home. About 7 percent of respondents were using some form of Unix at work, with Mac users slightly more likely (12 percent) to be using Unix than IBM-compatible PC users.

The choice of future operating systems, however, is not so clear. Those surveyed were asked, "Which of the following operating systems would you seriously

likely to spend even more time on business tasks than at work; on the average, 64 percent of time spent at the home PC is on business operations.

Among those who have PCs both at work and at home, fewer use the PC for engineering work than for business. More engineering work is done on PCs at the office by respondents (71.5 percent) than at home

High-end PCs (Mac or IBM-compatible): a representative sample of those available

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory[2]	Mass storage[2, 3]	Monitor[2]	Interfaces[2, 4]	Other features and options[4, 5]
Apple Computer Inc., Macintosh Quadra 950, $6099–$8149							
N.A.	Motorola 68040—33 MHz	System 7.1	Cache: internal, 8 KB RAM: 8 MB (256 MB), 80 ns	Internal, 500 MB (1000 MB)	(Monitor is optional)	E, SCSI, 2 serial,video, sound input	Stereo output from mono input; up to four 5.25-inch half-height storage devices may be installed; A/UX configuration also available
CompuAdd Computer Corp., CompuAdd 466 Oesktop Power, $2609–$9876, varies							
MIPS : 26.3; Landmark: 222.9; Norton 5.0: 127.8	Intel i486 DX2/66	MS DOS 5.0, MS Windows 3.1 (Interactive Systems Unix, OS/2 2.0)	Cache: internal, 8 KB; external, 64 KB (256 KB) RAM: 4 MB (64 MB), 80 ns	Internal, 80 MB (1 GB)	Color, 14-inch, 640 x 480 pixels (color, 14-inch, 1024 x 768, or 15-, 16-, 17-, or 20-inch, 1280 x 1024)	C, 2 serial (E, TR, ISDN SCSI, SCSI 2)	Upgradable with future Intel OverDrive processors based on Pentium architecture; flash BIOS for updating via software
Dell Computer Corp., Dell 450ME, $2799–$6710, 5 work days							
N.A.	N.A.	MS DOS 5.0, MS Windows 3.1 (Unix SVR4, OS/2 1.21)	Cache: internal, 8 KB; external, 128 KB RAM: 4–64 MB, 70 ns	Internal, 80 MB (1.4 GB)	Color, 14-inch, 1024 x 768	C (E, TR, SCSI 2)	—
Oolch Computer Systems, CPAC 486-66C, $7498–$20 262, 2 weeks							
MIPS : 27.5	Intel i486 DX2/66	(MS DOS 5.0, MS Windows 3.1, OS/2 2.0)	Cache: internal, 8 KB; external, 256 KB, 20 ns RAM: 4 MB (32 MB), 60 ns	Internal (120 MB, 1.0 GB)	Monochrome, 11.6-inch, 640 x 480 (color, 10.4-inch, 640 x 480)	C, RS-232C (SCSI, SCSI 2)	E, TR, and ISDN available from third parties
Intergraph Corp., Intergraph PC 466, $26 000, 2 weeks							
N.A.	Intel i486 DX2/66	(DOS)	Cache: internal, 8 KB; external, 256 KB (1 MB) RAM: 16 MB (32 MB), 80 ns	Internal, 426 MB	Color, 17- or 19-inch, 1024 x 768	E, C (TR)	Options include 18-by-13-inch digitizer with stylus ($995); second color monitor, 17- or 19-inch ($1500–$1900)
Micro Express, Micro Express ME 486-YL/DX2/66, $2495, 5 days							
MIPS : 9.7	Intel i486 DX2/66	MS DOS 5.0, MS Windows 3.1 (OS/2 2.2)	Cache: internal, 8 KB; external, 256 KB (1 MB) RAM: 4 MB (32 MB),80 ns	Internal, 200 MB (1.7 GB)	Color, 14-inch, 1024 x 768 (color, 20-inch, 1260 x 1024)	C (E, TR, ISDN, SCSI, SCSI 2)	Fax/modem optional; VESA local-bus graphics standard
Micron Computer Inc., Micron 486VL Computers Winstations 466, $1499–$$2699, 2 weeks							
MIPS : 20.6	Intel i486 DX2/66	MS DOS 5.0 (Unix, MS Windows 3.1, OS/2 2.1)	Cache: internal, 8 KB; external, 256 KB, 128 KB, 15 ns RAM: 16 MB (32 MB), 70 ns	Internal, 245 MB(80–1.7 GB)	Color, 15 inch, flat screen , 1280 x 1024 (color, 14- to 21-inch, 1024 x 768 to 1280 x 1024)	C (E, TR, SCSI, SCSI 2)	Multimedia kits and IDE caching and non-caching; VESA local bus; tower case option

(Table continued on following page)

(55.2 percent). And the amount of time spent on engineering and scientific tasks is greater at work (on average 32.7 percent) than at home (on average 20.5 percent).

As previously noted, about two-thirds of PC users at work are connected to networks and about half have modems. Not surprisingly then, about two-thirds spend some time communicating at their workplace. They do not, however, spend much time using their PCs to communicate; on the average, only 16 percent do. At work, even less time is spent using on-line data services. The average at-work on-line time, 3.1 percent, is about equal to the accuracy level of the survey.

Those who say they are not using a PC at work to perform engineering and communication functions are probably using a workstation for those tasks. A total of 208 respondents (31.7 percent) have a workstation at work, as well as a PC at home and at work. Of that group, 131, or 63 percent, noted that the work they do on their PC is completely separate and distinct from the work they do on their workstations. On the other hand, only about 4 percent of respondents have a workstation at home.

Although approximately two-thirds of the respondents have modems in their home computers, they do not spend much time communicating with others or with their computer at work. About 41 percent use their home computers for communication functions and only 23.7 percent use them to access on-line data services. On the average, they use their at-home PCs less for communications, but slightly more to access on-line data services. ◆

High-end PCs (Mac or IBM-compatible): a representative sample of those available *(continued)*

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory[2]	Mass storage[2, 3]	Monitor[2]	Interfaces[2, 4]	Other features and options[4, 5]
Modgraph Inc., GX-2486C-50, $5395–$6500, 3 weeks							
MIPS : 21	80486-50	(Xenix, MS DOS 5.0, MS Windows 3.1, OS/2)	Cache: internal, 8 KB; external,128 KB (256 KB) RAM: 4 MB (32 MB), N.A.	100 MB (540 MB)	Color, 7.5-inch, 800 x 600	C	Transportable,three drive bays, four expansion slots, and internal color Trinitron CRT
Polywell Computers Inc., Poly 486-66EV, $1950–$19 950, 10 days							
MIPS : 29.8	Intel i486-DX2/66	MS DOS 5.0, MS Windows 3.1 (SCO Unix, OS/2.0, Novell Netware)	Cache: internal, 8 K; external 256 K (512 K) RAM: 16 MB (256 MB), 60 ns	Internal, 1.2 GB (4 GB); external, 24 GB	Color, 17-inch, 1280 x 1024 (color, 20-inch, 1280 x 1024)	SCSI 2, C, 32-bit VESA local bus (E, TR, ISDN, SCSI)	Combines EISA with VESA 32-bit bus: uses EISA SCSI-2 disk controller and VESA graphic accelerator; upgradable to Intel Pentium processor, when available
Tandy Corp., Tandy 466 DX2, $1778, 48 hours							
N.A.	Intel i486 DX2/66	MS DOS 5.0, MS Windows 3.1	Cache: internal, 8 KB; external (256 KB) RAM: 2 MB (40 MB), 80 ns	(Internal, 340 MB)	(Monochrome, 14-inch, 1024 x 768)	(C)	—
Unisys Corp., PW 2 Advantage Plus Model 4666, $3953–$5353, immediate							
Wingraph 3.1: 20	Intel i486 DX2/66	MS DOS 5.0, MS Windows 3.1 (SCO Unix, OS/2 1.2, Netware)	Cache: internal, 8 KB; external, 256 KB RAM: 8 MB (128 MB), 80 ns	Internal, 340 MB (1 GB)	(Color, 14-inch, 1024 x 768)	SCSI 2, C, 2 serial, UPS signal port (E, TR)	Upgradable to Intel Pentium processor, when available

N.A. = not available from the vendors.
1 MIPS = millions of instructions per second. 2 Terms in parentheses indicate options offered by vendors. 3 Optional cache and RAM sizes in parentheses are maxima.
4 C = Centronics/parallel; E = Ethernet; ISDN = Integrated-Services Digital Network; TR = token ring; SCSI = small computer systems interface; VESA = Video Electronics Standards Association; UPS = uninterruptible power supply. 5 BIOS = built-in operating system; EISA = extended industry standard architecture; IOE = Interactive Data Entry

En

Model 715/33 • 46 SPECmark89 • 24.2 SPECint
45 SPECfp • 15" color • 16MB diskless
1 EISA slot (optional) • $5,695

Model 715/33 • 46 SPECmark89 • 24.2 SPECint
45 SPECfp • 19" color • 16MB, 525MB
1 EISA slot (optional) • $9,995

Model 725/50 • 69 SPECmark89 • 36.5 SPECint
72.1 SPECfp • 19" grayscale • 32MB, 525MB
4 EISA slots • $17,895

Model 735 • 147 SPECmark89 • 80 SPECint
150.6 SPECfp • 19" color • 32MB , 525MB
1 EISA slot • $37,395

Model 755 • 147 SPECmark89 • 80 SPECint
150.6 SPECfp • 19" color • 64MB, 2.0GB
4 EISA slots • $58,995

What can you do after making the world's best performing workstations? Do it again.

When you're hot, you're hot. And our new generation of HP Apollo 9000 Series 700 workstations sizzles. With performance far ahead of anything else on this or any other known planet. But at extremely down-to-earth prices.

Our new generation PA-RISC is the catalyst for the latest advances. Providing a color entry-level system with phenomenal performance for just $5,695. 3D graphics available across the entire product line, even the low end. And a breathtaking 147 SPECmarks at the high end.

Think for a moment what all this could do for you. Then don't waste another moment before calling **1-800-637-7740, Ext. 7207.** We'll give you an encore dramatically better than the original performance.

HEWLETT
PACKARD

Circle No. 210

Workstation metrics

Users can predict how well different classes of computers will perform various tasks if they really understand what a set of benchmarks tests

Perhaps the biggest obstacle that would-be computer users face is deciding which of all the possible systems provides the best performance for a given role... and a given budget. Accordingly, both computer users and manufacturers have tried to define ways of measuring performance so that fair comparisons may be made between systems.

These measurement methods, called benchmarks, were typically developed in relation to particular classes of computers, such as PCs, workstations, and mainframes. With the advances in microprocessors, however, the boundaries are blurring: microprocessors based on one type of reduced–instruction-set computing (RISC) architecture are at the heart of everything from desktop computers to massively parallel superservers and graphics systems. This development is becoming the basis for a more nearly common set of benchmarks, one that may be used on any class of system, because it can be scaled meaningfully, with both processor clock rates and the use of shared-memory symmetric parallelism.

BENCHMARK GOAL. Because one person's benchmark is another's red herring, even when members of the same set of systems are being compared, it is critical to identify who is the "customer" for a benchmark before determining the type most useful to him or her. Table 1 indicates the four basic classes of users. It is also possible to divide the world into scientific and business classes, the latter being interested in transaction-processing benchmarks such as TPA. Scientific users are the focus here, though.

As the benchmarks for the four classes will probably be at odds with one another, each type of user will utilize a different set, though the various sets may have some overlap. Additionally, as computer system architectures incorporate digital media technologies like three-dimensional graphics, audio, and video, their growing complexity is eliciting increasingly complex benchmarking "suites." These suites measure the effects on performance associated with complicated operations combining the use of the CPU, memory, secondary disk storage, I/O, and graphics. When exercised at the same time, one or more of these elements may prove to be a bottleneck to the others, highlighting occasions when the system architecture is not balanced.

A PRIMER. Computer systems have evolved rapidly over the past two decades, taking advantage of ever faster buses and processors and custom application-specific ICs (ASICs). As a result, many of the benchmarks of 10 years ago are of little relevance today. Before the era of multi-media or 3-D graphics, computers computed and output to printers or CRTs, but did little else. It was then that the measure of MIPS (million instructions per second) arose to compare the speeds of different processors or computer systems.

MIPS, though, measures only integer operations. So next came Mflops (million floating-point operations per second), since most scientists and engineers perform floating-point–intensive computations. A variety of benchmarks have been defined for measuring MIPS and Mflops on heterogeneous systems. The most common are the Dhrystone (for MIPS) and Linpack (for Mflops).

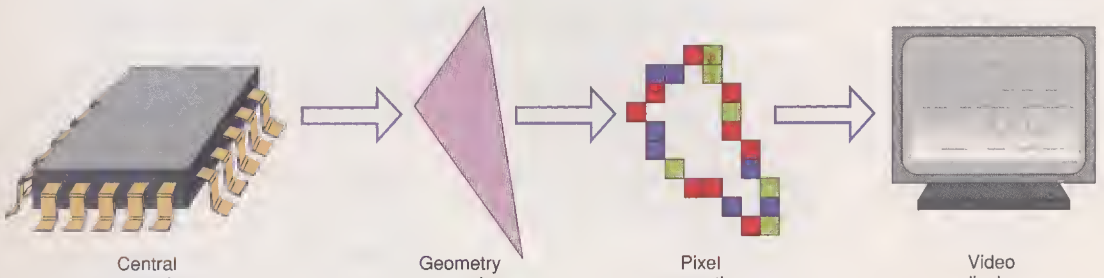
The Dhrystone benchmark is a way of measuring a system's ability to perform integer math (a Dhrystone is defined as being equal to a VAX integer MIPS multiplied by 1757). The benchmark program is first compiled and then run on the system and its execution time is monitored. However, both the compiler and the computer can be optimized to give a high Dhrystone rating without improving a machine's performance on typical programs.

The first floating-point benchmark and companion to the Dhrystone was, appropriately enough, the Whetstone. Based on the use of numerous transcendental functions, it came in a single-precision and a double-precision version. But like the Dhrystone, it was too amenable to compiler and hardware tinkering that overstated the performance of typical programs.

The Linpack floating-point benchmark was at least derived from a practical set of applications. It solves dense sets of linear equations, typically involving 100-by-100- and 1000-by-1000-element matrices. While Linpack was once considered effective, the widespread use of cache in today's machines has reduced its usefulness. The Linpack benchmark is a relatively small program that can fit into most caches today, and so does not test the overall system.

In all these measures, the fatal flaw is that it is always possible to design a computer system to perform well on the benchmark—and much less well on real applications. All too many of these benchmarks represent peak rather than sustained performance and

Joshua Mogal Silicon Graphics Inc.



[1] To draw an image, a computer's main processor sends general commands to its graphics system, which first extracts from them the data needed to calculate the shapes that make up the image. It then turns the shapes into textured, shaded pixels for display.

0018-9235/93/$3.00©1993 IEEE

1. Benchmark user classes

Classes	Description
Single-application end user	Runs a single application type on the system most of the time; needs a single set of performance characteristics
Multiple-application end user	Runs a range of applications on the system; needs a range of performance characteristics
Computer manufacturer marketing staff	Encourages engineering staff to design system that will perform well on industry-standard benchmarks; needs benchmarks that prove capabilities of system to target customers
Computer manufacturer design engineer	Designs systems for optimum performance; needs benchmarks to determine whether new technology addresses requirements of targeted users

thus are a poor reflection of the performance to be expected in use.

Computer design involves countless tradeoffs. Many RISC processors in use today—the Digital Equipment Alpha, Hewlett-Packard PA-RISC, IBM RS/6000, Intel i860, MIPS R4400, and Sun Sparc—provide a mix of 32- and 64-bit capabilities for addressing and computation, as well as assorted cache sizes, levels, and buses. These variations in the core architecture often produce widely varying benchmark results.

Raw speed counts for something, but not everything, since application software rarely executes in constant burst mode. Instead, most computers support multiple, simultaneous processes, so that the processor must switch from executing one to executing another. Achieving solid performance in this area is critical for multi-user and multiprocessing environments, where computational resources are not always single-tasked. Thus, throughput becomes as critical a metric as raw computational speed.

Of most interest to computer customers is not how many MIPS, Mflops, or polygons per second the system can deliver, but rather how it performs when executing their chosen types of applications. This interest is evidenced in the trend toward benchmarking suites like SPEC, AIM, and Khornerstone.

BALANCED SYSTEM ASSESSMENT. To provide a balanced view, a benchmark must therefore take into account the performance achievable while putting the entire system through its paces, from the cache and main memory to the disk, I/O, and compute subsystems as well.

The most widely used benchmark suite today is the application-oriented one created by the SPEC organization. The original benchmark created in 1989, Spec89, has been followed by Specint92 and Specfp92, while a lesser-known Spec suite measures system throughput. However, as Spec89 was becoming popular, it was found that system manufacturers could optimize their systems for certain portions of the suite, and so skew averages to imply better than realistic performance. In an attempt to overcome this problem, Specint92 and Specfp92 were created.

Specint92 and Specfp92 are each sets of five routines based on sample code from chemistry, physics, robotics, math, compiler, and other real applications. Released in 1992 they evaluate a system's integer and floating-point performance, respectively. In both cases, benchmark results are usually quoted as single numbers, which are weighted averages of the results for all routines. Still, it is possible to obtain the result for each of the routines separately, to see if any one skews the total number. (A claim of high performance based on a single process is considered suspicious, since it does not evaluate context-switching or multiprocessing capability.)

Khornerstone and AIM lack the broad appeal of the Spec suites. The first combines the Whetstone and Dhrystone benchmarks with Savage (a set of scientific math functions), Sieve (a prime number generator), Fibonnaci (recursion handling), and Ackerman-function (recursion and processor performance) routines. Results from these C and Fortran routines are weighted and averaged. The suite covers integer and floating-point math for large and small

2. Graphic performance specification for three typical systems

Metric name	Description	Typical performance, thousands per second (italic numbers = bits)		
		X	Y	Z
3-D Vectors/s	Number of 3-D vectors that can be drawn in one second; *vectors should be connected, 10 pixels long, Gouraud-shaded, clip-tested, Z-buffered, depth-cued, and anti-aliased*	2	1.2[a]	3[a, b, c,]
3-D Quads/s	Number of 3-D, four-sided polygons that can be drawn in one second; *polygons should cover a 100-pixel area and be independent, arbitrarily oriented, Gouraud-shaded, Phong-lighted, clip-tested, Z-buffered, and anti-aliased*	0.9	0.15[d]	0.6[b, c, d]
3-D Tmesh polygons/s	Number of 3-D, three-sided polygons meshed into strips that can be drawn in one second; *polygons should cover a 50-pixel area and be arbitrarily oriented, flat-shaded, clip-tested, Z-buffered, and anti-aliased*	1.6	0.6	1.9[b, c,]
3-D TexTmesh polygons/s	Number of 3-D, three-sided polygons—with a tri-linear, mip-mapped texture and meshed into strips—that can be drawn in one second; *polygons should cover a 50-pixel area and be arbitrarily oriented, Gouraud-shaded, Phong-lighted, clip-tested, Z-buffered, fogged, and anti-aliased*	0.9	—[e]	0.24[a, b, c, f]
Flat pixel fill rate	Number of pixels a system can write to frame buffer per second for *flat-shaded* points, vectors, and polygons	90–360	Not published	95
Textured pixel fill rate	Number of pixels a system can write to frame buffer per second for tri-linear, mip-mapped texture points, vectors, and polygons that are *Gouraud-shaded, Phong-lighted, fogged, and anti-aliased*	80–320	—[e]	12[g]
Image bit-planes	Maximum number of bits used to hold color in frame buffer	*36*	*24*	*24*
Alpha bit-planes	Maximum number of bits used to hold transparency in frame buffer	*12*	—	*8*
Z-buffer bit-planes	Maximum number of bits used to hold depth information in frame buffer	*32*	*23*	*32*
Double buffering	Maximum number of color/transparency planes supported in each of the front and back buffers for smooth rendering of dynamic graphics	*48*	*24*	*32*

a For flat, not Gouraud, shading. b Requires multiprocessor version of system with special cache to reach specified performance.
c Without clip-testing. d Without anti-aliasing. e System does not support textures. f Without fogging.
g Texture fill, though not specified, may be derived from the polygon size (50 pixels) multiplied by the number of 3-D TexTmesh polygons per second (240 000).

dataset and test disk, memory, and I/O performance.

As for AIM Suite III, its 33 tests may be combined to assess multiuser performance, producing a weighted and averaged result. Its weighting percentages are: 20 percent each for RAM, disk, logic, and math performance and 10 percent each for floating-point and pipelining. Even though the benchmarking suites have been designed for balance and for the evaluation of complete systems, they rank systems differently, depending upon what is being looked for. Note also that the Khornerstone and AIM suites are affected by varying levels of memory.

As yet, there are no benchmarking suites that stress entire system architectures with graphics capability included. Even the most comprehensive of them make no allowance for the impact of the graphics subsystem on computational performance.

PARALLEL PROCESSING. The problem of creating a benchmark that is consistent across heterogeneous vendors' platforms has grown worse with the introduction of massively parallel-processing (MPP) and symmetric multiprocessing (SMP) systems. Parallel-processing technologies were once the domain of supercomputers, but in recent years, SMP architectures have made their way into deskside workstations and indeed into every type of system. Thus it is all the more important that benchmarks give a clear understanding of how application performance can scale with the number of CPUs utilized.

"What counts is performance delivered on user codes," said George Cybenko and David J. Kuck, "and not idealized computation rates based on the capabilities of exotic semiconductors" ["Revolution or evolution?," *IEEE Spectrum*, September 1992, pp. 39–41]. Using the Numerical Aerodynamic Simulation (NAS) parallel benchmark's fast Fourier transform (FFT), multi- and vector-processor supercomputers ranged from 4 to 30 percent efficiency when the actual gigaflops they achieved was compared with the peak number quoted. These results encouraged the development of the Perfect Benchmarks, coordinated by the University of Illinois, Urbana-Champaign. Cybenko has said, "The Perfect Benchmark data demonstrate the complexity of computer systems performance. Put another way, no single number captures performance in any meaningful way and, conversely, efforts to quantify performance by a single number are intrinsically oversimplified" ["Supercomputer Performance Trends and the PERFECT Benchmarks," *Supercomputing Review*, April 1991].

When comparing graphics workstations, the problem becomes still worse. They have both general-purpose computational and specialized graphics subsystems, requiring benchmarks that measure each individually and estimate the balance between the two main subsystems, that is, their ability to work together efficiently.

Graphics performance has proven very difficult to measure, as few real "standard" benchmarks were available until the very recent Picture Level Benchmark (PLB) was announced by the Graphics Performance Characterization (GPC) committee of the National Computer Graphics Association, Fairfax, Va. The PLB is an attempt to provide a common set of benchmarks for comparing different graphics systems fairly.

GRAPHICS ROADBLOCK. The roadblock has been that no standard graphics library existed with which the benchmark could be written. Each computer system vendor supported a variety of graphics libraries, including GKS, Phigs, Starbase, the Silicon Graphics GL, and others also.

In 1991, Silicon Graphics Inc., Mountain View, Calif., opened up access to its proprietary GL graphics library, establishing OpenGL as a universally accessible graphics library standard. Now licensed by Digital Equipment Corp., IBM, Intel, Intergraph, Microsoft, and Novell, among others, OpenGL is well on its way to providing a common basis for the development and utilization of common 2-D and 3-D graphics benchmarks.

Even though a common basis has been found for writing the benchmarks, agreement has yet to be reached on exactly what measurement a graphics metrics requires to characterize the overall graphics performance of a given computer system. The process of generating 3-D computer graphics, however, is performed in a similar fashion on virtually all of the general-purpose graphics workstations currently on the market [Fig. 1].

The CPU subsystem transmits 3-D and 2-D graphics and image data across a cable or bus to the graphics pipeline. This data is typically communicated in one of two methods: Display List mode and Immediate mode. Display lists are strictly ordered lists of geometric objects along with their spatial transformations (rotations, translations, scaling) and lighting. Being predefined, the list is tightly organized and efficient. Unfortunately, it also means that making changes to the list can be very difficult or costly from a performance perspective.

Immediate Mode graphics, on the other hand, is performed by sending geometry down to the graphics pipeline as it is generated by the application in the CPU, a polygon or vector at a time. Although this is much less structured than display list graphics, it does not reduce performance much, because the graphics pipeline rarely waits for the CPU to build up a new data set, but processes data on the fly. The primary advantage of Immediate Mode graphics is that geometry can be easily changed from one rendered frame to the next, avoiding a complete restructuring of a display list.

Once in the graphics pipeline, the 3-D data is transformed geometrically at the

(Continued on p. 57)

Workstations: a representative sample of those available

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory[2,3]	Mass storage[2,4]	Monitor[2]	Interfaces[2,5]	Other features and options[6]
Low end (under $10 000)							
Aries Research Inc., Parrot II, $5995–$12 560, 5–10 days							
MIPS, 28.5; Mflops, 4.2; Specmarks, 24.7	Sun Sparc	Solaris 1.1	Cache: 64 KB RAM: 32 MB (64 MB on board, 128 MB with Sbus card)	Internal, 424 MB (1 GB); external, 9 GB	Color, 19-inch, 1150 x 900 pixels	E, SCSI 2, two serial	Archive tape backup and Sony CD ROM are optional
CompuAdd Computer Corp., CompuAdd SS1+, $5295–$15 785, varies							
MIPS, 15.8; Mflops, 1.7; Specmarks, 11.8	SS1+	Solaris 1.0.1	Cache: external 64 KB, 80 ns RAM: 8 MB (64 MB with 4 MB SIMM), 80 ns	Internal, 104 MB (420 MB); external, 2.4 GB	Monochrome, 19-inch (color, 16-, 19-inch), 1152 x 900	E, SCSI, two serial audio ports	100% binary compatibility with Sun Sparcstation; accepts all its accessories and peripherals
Force Computers Inc., Sparc CPU-ZCE, $7995, 4 weeks							
MIPS , 28.5; Mflops, 4.2	Sparc 2	Solaris 1.x, 2.x	Cache: external, 32 KB RAM: 16 MB (128 MB)	N.A.	N.A.	E, SCSI	100% compatible with Sparcstation 2, whose architecture is embedded in a VMEbus-based board
Hewlett-Packard Co., HP Apollo 9000 Series 700 Model 715/33, $5695–$40 345, 4 weeks							
MIPS, 41; Mflops, 8.6; Specmarks, 45.9; Specint92, 24.2; Specfp92, 45	PA-7100 chip	HP-UX	Cache: external, 128 KB RAM: 16 MB (192 MB)	Internal, diskless, 2 GB; external, 69.7 GB	Color, 15-inch (mono, 19-inch), both 1280 x 1074	(TR, ISDN, SCSI 2, parallel)	16-bit CD/DAT quality audio
IBM Coro., RS/6000 Powerstation 220, $3795, 1 week							
						(TR,	Two MicroChannel slots for expansion
						erial, ree ots	Options include 150-MB archive or 535-MB tape backup and external 660-MB CD ROM
						2	Portable workstation 100% Sun-compatible
						2, , serial, TR, FDDI, VAS, video)	Supports 16-bit stereo audio, real-time video and 3-D graphics; graphical system administration
						CSI 2 TR,	Comes with 8-bit graphics, integrated networking, expandable Sbus slots as well as 8-bit audio
MIPS, 20.4, Mflops, 4, 6; Xstones, 14 000	Motorola		KB; RAM: 16 MB (64 MB)	MB (1 GB); External, 10 GB	19-inch, 1280 x 1024 (mono, color, 1600 x 1200)	SI (parallel)	—
CompuAdd Computer Corp., CompuAdd SS2, $11 995–$24 979, varies							
MIPS , 28.5; Mflops, 4.2; Specmarks, 21	SS2 "Calvin"	Solaris 1.0.1	Cache: 64 KB, 80 ns, RAM: 16MB (64MB), 80 ns	Internal, 425 MB (850 MB); external, 208 GB	Color (mono), 19-inch, 1152 x 900	E, SCSI	100% binary compatible with Sun Sparcstation; accepts all its accessories

dataset and test disk, memory, and I/O performance.

As for AIM Suite III, its 33 tests may be combined to assess multiuser performance, producing a weighted and averaged result. Its weighting percentages are: 20 percent each for RAM, disk, logic, and math performance and 10 percent each for floating-point and pipelining. Even though the benchmarking suites have been designed for balance and for the evaluation of complete systems, they rank systems differently, depending upon what is being looked for. Note also that the Khornerstone and AIM suites are affected by varying levels of memory.

As yet, there are no benchmarking suites that stress entire system architectures with graphics capability included. Even the most comprehensive of them make no allowance for the impact of the graphics subsystem on computational performance.

PARALLEL PROCESSING. The problem of creating a benchmark that is consistent across heterogeneous vendors' platforms has grown worse with the introduction of massively parallel-processing (MPP) and symmetric multiprocessing (SMP) systems. Parallel-processing technologies were once the domain of supercomputers, but in recent years, SMP architectures have made their

Graphics performance has proven very difficult to measure, as few real "standard" benchmarks were available until the very recent Picture Level Benchmark (PLB) was announced by the Graphics Performance Characterization (GPC) committee of the National Computer Graphics Association, Fairfax, Va. The PLB is an attempt to provide a common set of benchmarks for comparing different graphics systems fairly.

GRAPHICS ROADBLOCK. The roadblock has been that no standard graphics library existed with which the benchmark could be written. Each computer system vendor supported a variety of graphics libraries, including GKS, Phigs, Starbase, the Silicon Graphics GL, and others also.

In 1991, Silicon Graphics Inc., Mountain View, Calif., opened up access to its proprietary GL graphics library, establishing OpenGL as a universally accessible graphics library standard. Now licensed by Digital Equipment Corp., IBM, Intel, Intergraph, Microsoft, and Novell, among others, OpenGL is well on its way to providing a common basis for the development and utilization of common 2-D and 3-D graphics benchmarks.

Even though a common basis has been found for writing the benchmarks

Review, April 1991).

When comparing graphics workstations, the problem becomes still worse. They have both general-purpose computational and specialized graphics subsystems, requiring benchmarks that measure each individually and estimate the balance between the two main subsystems, that is, their ability to work together efficiently.

waits for the CPU to build up a new data set, but processes data on the fly. The primary advantage of Immediate Mode graphics is that geometry can be easily changed from one rendered frame to the next, avoiding a complete restructuring of a display list.

Once in the graphics pipeline, the 3-D data is transformed geometrically at the

(Continued on p. 57)

Workstations: a representative sample of those available

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory[2,3]	Mass storage[2,4]	Monitor[2]	Interfaces[2,5]	Other features and options[6]
Low end (under $10 000)							
Aries Research Inc., Parrot II, $5995–$12 560, 5–10 days							
MIPS, 28.5; Mflops, 4.2; Specmarks, 24.7	Sun Sparc	Solaris 1.1	Cache: 64 KB RAM: 32 MB (64 MB on board, 128 MB with Sbus card)	Internal, 424 MB (1 GB); external, 9 GB	Color, 19-inch, 1150 x 900 pixels	E, SCSI 2, two serial	Archive tape backup and Sony CD ROM are optional
CompuAdd Computer Corp., CompuAdd SS1+, $5295–$15 785, varies							
MIPS, 15.8; Mflops, 1.7; Specmarks, 11.8	SS1+	Solaris 1.0.1	Cache: external 64 KB, 80 ns RAM: 8 MB (64 MB with 4 MB SIMM), 80 ns	Internal, 104 MB (420 MB); external, 2.4 GB	Monochrome, 19-inch (color, 16-, 19-inch), 1152 x 900	E, SCSI, two serial audio ports	100% binary compatibility with Sun Sparcstation; accepts all its accessories and peripherals
Force Computers Inc., Sparc CPU-ZCE, $7995, 4 weeks							
MIPS , 28.5; Mflops, 4.2	Sparc 2	Solaris 1.x, 2.x	Cache: external, 32 KB RAM: 16 MB (128 MB)	N.A.	N.A.	E, SCSI	100% compatible with Sparcstation 2, whose architecture is embedded in a VMEbus-based board
Hewlett-Packard Co., HP Apollo 9000 Series 700 Model 715/33, $5695–$40 345, 4 weeks							
MIPS, 41; Mflops, 8.6; Specmarks, 45.9; Specint92, 24.2; Specfp92, 45	PA-7100 chip	HP-UX	Cache: external, 128 KB RAM: 16 MB (192 MB)	Internal, diskless, 2 GB; external, 69.7 GB	Color, 15-inch (mono, 19-inch), both 1280 x 1074	(TR, ISDN, SCSI 2, parallel)	16-bit CD/DAT quality audio
IBM Corp., RS/6000 Powerstation 220, $3795, 1 week							
MIPS, N.A.; Mflops, 6.6; Specmarks, 27.7; Specint92, 16.6; Specfp92, 26.1	Single-chip Power architecture	AIX 3.2	Cache: internal, 8 KB RAM: 16 MB (64 MB)	Internal, 400 MB (1 GB); external, 9.5 MB	(Color, 16-, 19-, or 23-inch, 1280 x 1024)	E, SCSI (TR, SCSI 2)	Two MicroChannel slots for expansion
Mobius Computer Corp., Mirage Series, Model IPS/2, $5080–$7995, 7–10 days, ARO							
MIPS, 28.5; Mflops, 4.2; Specs, 24; Xstones, 89 000	Sparc 2	Solaris 1.1, 2.1	Cache: internal, 64 KB RAM: 16 MB (128 MB)	Diskless (525 MB); external, 4 GB	Color, 17-inch, 1152 x 900	E, two serial, SCSI, three Sbus slots	Options include 150-MB archive or 535-MB tape backup and external 660-MB CD ROM
RDI Computer Corp., BriteLite IPC Color, $9995–$13 895, 45 days							
MIPS, 17.8; Mflops, 1.8; Specint92, 13.8; Specfp92, 11.1	Sparcengine IPC	SunOS 4.1.3	Cache: internal, 128 KB RAM: 8 MB (46 MB), 80 ns	Internal, 450 MB	Color, 10-inch, 640 x 480	E, SCSI 2	Portable workstation 100% Sun-compatible
Silicon Graphics Inc., Indigo Entry R3000, $6995, 1 week							
MIPS, 30; Mflops, 4.3; Specmarks, 26; Specint92, 22.4; Specfp92, 24.2; Khornerstones, 100 261; AIM, 31.4	MIPS R3000 with R30104 floating-point unit	Unix SVR4 (Insignia DOS, MS Windows 3.1)	Cache: external, 64 KB RAM: 16 MB (96 MB)	Internal (3.6 GB); external, 8.4 GB	Color, 17-inch (color, 20-inch), both 1024 x 768	E, SCSI 2, parallel, serial, audio (TR, ISDN, FDDI, ATM, IVAS, VLAN, video)	Supports 16-bit stereo audio, real-time video and 3-D graphics; graphical system administration
Sun Microsystems Inc., SPARCclassic, $3995–$4295, now							
MIPS, 59.1; Mflops,4.6; Specint92, 26.4; Specfp92, 21.0	MicroSparc390 S10	Solaris 2.1	Cache: internal, 6 KB RAM: 16 MB (96 MB), 60 ns	Internal, 207 MB, 424 MB; external, 22 GB	Color, 15-inch, 1024 x 768	E, C, SCSI 2 serial (TR, ISDN)	Comes with 8-bit graphics, integrated networking, expandable Sbus slots as well as 8-bit audio
Mid-range ($10 000–$45 000)							
Cetia, Cetia 1000, $13 000, N.A.							
MIPS, 26.4; Mflops, 4, 6; Xstones, 14 000	Motorola 68040	Unix V	Cache: internal, 8 KB; RAM: 16 MB (64 MB)	Internal, 400 MB (1 GB); External, 10 GB	Mono (color), 19-inch, 1280 x 1024 (mono, color, 1600 x 1200)	E, SCSI (parallel)	—
CompuAdd Computer Corp., CompuAdd SS2, $11 995–$24 979, varies							
MIPS , 28.5; Mflops, 4.2; Specmarks, 21	SS2 "Calvin"	Solaris 1.0.1	Cache: 64 KB, 80 ns, RAM: 16MB (64MB), 80 ns	Internal, 425 MB (850 MB); external, 208 GB	Color (mono), 19-inch, 1152 x 900	E, SCSI	100% binary compatible with Sun Sparcstation; accepts all its accessories

Workstations: a representative sample of those available *(continued)*

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory[2,3]	Mass storage[2,4]	Monitor[2]	Interfaces[2,5]	Other features and options[6]
Mid-range ($10 000–$45 000) *(continued)*							
Concurrent Computer Corp., Series 7000 Multiprocessing Systems, $20 000–$150 000, 90 days ARO							
MIPS, 20.0; Mflops, 2.16M; Specmarks, 11.1	Motorola 68040, 33 MHz (to three processors)	RTU	Cache: internal 8 KB RAM: 16 MB (104 MB)	Internal, 200 MB (2.9 GB); external, 105 GB	Color, 19-, 16-inch, 1280 x 1024	E, SCSI, SCSI 2 (parallel, IBIM)	Supports SCSI, SCSI 2, IPI, optical, and tape storage devices; has 12- and 16-bit AD, DA; IEEE 488; accelerator for floating-point vector math
Digital Equipment Corp., DEC 3000 Model 400 AXP, $14 995–$36 995, 30 days							
MIPS , 134; Mflops, 26.4; Specmarks, 108.1; Specint92, 65.3; Specfp92, 112.1	AXP 21064, 133 MHz	OSF/1 or open VMS (DOS)	Cache: internal, 16 KB; external, 512 KB RAM: 32 MB (128 MB)	Internal, 426 MB (2.1 GB); external, 9.5 GB	Mono, 17-inch (color, 19-inch), both 1280 x 1024	E, ISDN, SCSI 2 (parallel, IPI, FDDI, TR, VME)	Includes 2-D graphics accelerator, Multiscreen, Prestoserve, 3-D graphics optional
Force Computers Inc., Tera Force-2CE, $19 500–$29 500, 4 weeks							
MIPS, 28.5; Mflops, 4.2	Sparc 2	Solaris 1.x, 2.x	Cache: external, 64 KB RAM: 16 MB (128 MB)	Internal, 420 MB (1.2 GB), 2.0, 30 GB; external, 30 GB	Mono (color), 19-inch, both 1280 x 1024	E, SCSI, Sbus, serial	100% compatible with Sparcstation 2, whose architecture is embedded in a VMEbus-based system; 14 VMEbus expansion slots; includes tape backup
Hewlett-Packard Co., HP Apollo 9000 Series 700, Model 715/50, $11 895–$55 495, 4 weeks							
MIPS, 62; Mflops, 13; Specmarks, 69; Specint92, 36; Specfp92, 72	PA-7100	HP-UX 7.01	Cache: external, 128 KB RAM: 16 MB (256 MB)	Internal, 525 MB (2 GB); external, 69.7 GB	Grayscale, 19-inch, 1280 x 1024 (color, 17-inch, 1024 x 768, or 19-inch, 1280 x 1024)	E, SCSI, SCSI 2 (TR, ISDN)	11-bit, CD/DAT-quality stereo
Intergraph Corp., InterPro 2730, $14 900–$20 900							
MIPS, 68.2; Specint92, 24.5; Specfp92, 35.8	Clipper C400	Unix SVR 3	Cache: internal, 32 KB RAM: 32 MB (128 MB), 80 ns	Internal, 426 MB or 1 GB; external, 8.4 GB	Color, 19-inch, 1184 x 884 (color, 21-, 27-inch, both 1664 x 1248)	E, SCSI Versatec, serial TR	Additional 19-inch monitor $5000, optional ergonomic furniture
Marathon International/OEM Engines, Sparc Model 35/40, $10 000, 3–5 days							
MIPS, 35	OEM engines, 35/40	Unix, SunOS, (Solaris 4.1.3)	RAM: 16 MB (96 MB)	Internal, 424 MB (1.6 GB)	Color, 1152 x 900	ISDN, SCSI 2, Audio I/O	—
Microway Inc. , 486B3/Q860, $25 000–$50 000,1 to 3 weeks							
MIPS, 28.87; Mflops, 200	Intel 486 DX2/66	(Unix V3, V4; Coherent, MS DOS, Solaris, OS/2 2.01)	Cache: internal, 8 KB; external, 256 KB (512 KB) RAM: 16 MB (256 MB), 60 ns	Internal, 213 MB (10 GB)	Color, 14-inch, 1024 x 768 (color, 17-inch, 1280 x 1024)	—	Includes NDP Fortran, C/C++ or Pascal compiler; 2-MB dedicated memory per i860
Mobius Computer Corp., Mirage IPS/10, $12 995–$14 995							
MIPS , 101; Mflops, 20; Specint92, 45; Specfp, 92; Xstones, 95 000	Sparc 10 (TI SuperSparc 36 MHz)	Solaris 1.1, 2.1	Cache: internal, 64 KB (512 MB) RAM: 16 MB (64 MB), 70 ns	Internal, diskless (2 GB)	Color, 17-inch 1152 x 900 (color, 19-inch, 1152 x 900)	E, two serial, SCSI 2 (E, TR, ISDN parallel)	—
RDI Computer Corp., BriteLite LX, $15 995–$26 495, 60 days							
MIPS, 59.1; Mflops, 4.6; Specint92, 26.4; Specfp92, 21.0	Sparcengine LX	Solaris 2.1	Cache: internal, 6 KB RAM: 16 MB (96 MB), 60 ns	Internal, 450 MB; external, 15 GB	Color, 10.5-inch, 640 x 480	E, ISDN, SCSI 2, parallel	Active-matrix Colorplus LCD provides 256 000 selectable colors
Silicon Graphics Inc., Indigo 2 Extreme, $35 000, 30 days							
MIPS, 100; Mflops, 16; Specmarks, 70; Specint92, 59; Specfp92, 61	MIPS R4000	Unix SVR4	Cache: internal, 16 KB; external, 1 MB, 15 ns RAM: 32 MB (384 MB), 80 ns	Internal, 1 GB (3 GB); external, 7 GB	Color, 19-inch, 1280 x 1024	E, SCSI, parallel, two serial, five audio (FDDI)	EISA-bus expandability, optional processor upgrade to 150-MHz R4400 processor

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory[2 3]	Mass storage[2 4]	Monitor[2]	Interfaces[2, 5]	Other features and options[6]
Sun Microsystems Computer Corp., Sparcstation 10 Model 41 GS, $26 995, 30–90 days							
MIPS, 109.5; Mflops, 22.4; Specint92, 53.2; Specfp92, 63.4	TI Supersparc	Solaris 2.1	Cache: internal 36 KB ; external, 1 MB (4 MB) RAM: 32 MB (512 MB)	Internal, 424 MB or 1.05 GB (21 GB); external, 41 GB	Color, 19-inch, 1152 x 900	E, ISDN, SCSI 2, parallel, two serial (TR)	—
Tatung Science and Technology Inc., Super Compstation 7/30, $16 290, N.A.							
MIPS, 86.1; Mflops, 10.6; Specint92, 44.2; Specfp92, 52.9	TI SuperSparc	Solaris 1.1 or 2.1	RAM: 32 MB (256 MB)	Internal, 1 GB (2 GB); external, 12 GB	Color, 19-inch (color, 17-inch), both 1152 x 900	E, SCSI 2, parallel (ISDN, SCSI)	—
High end (over $45 000)							
Digital Equipment Corp. , DEC 3000 Model 500 AXP, $38 995–$60 000+, 30 days							
MIPS, 151; Mflops, 30.1; Specmarks, 121.5; Specint92, 74.3; Specfp92, 126.0	DEC AXP 21064, 150 MHz	OSF/1 or open VMS (DOS MS Windows via emulation)	Cache: internal, 16 KB; external, 512 KB RAM: 32 MB (512 MB)	Internal, 1 GB (4.2 GB); external, 11.6 GB	Color, 19-inch, 1280 x 1024	E, ISDN, two SCSI 2 (parallel IPI, FDDI, VME)	Options include Multiscreen, Prestoserve, 3-D graphics; includes 2-D graphics accelerator
Hewlett-Packard Co., HP Apollo 9000 Series 700, Model 735 CRX-2YZ, $48 045–$112 445, 6 weeks							
MIPS, 124; Mflops, 40; Specmarks, 147; Specint92, 8; SpecFP92, 150	PA-7100	HP-UX 9.01	Cache: external, 256 KB RAM: 32 MB (400 MB)	Internal, 520 MB (2 GB); external, 125.4 GB	Color, 19-inch, 1280 x 1024	E, SCSI 2, parallel, FDDI	Features 24-plane accelerated color subsystem
Intergraph Corp., Inter Pro 6880, $33 900–$56 900, N.A.							
MIPS, 85; Mflops, 16.3; Specint92, 36.1; Specfp92, 65.6	Clipper C400	Unix SVR 3	Cache: 16 KB each instruction and data, RAM: 32 MB (512 MB), 60 ns	Internal, 1 GB (1 GB); external, 8.4 GB	Color, 19-inch 1184 x 884, 27-inch, 1664 x 1248	E (TR), SCSI 2, O Versatec, FDDI, serial X.25	Ergonomic furniture
Silicon Graphics Inc., Onyx/Reality Engine 2, $163 400, 1 week							
Per CPU—MIPS, 127; Mflops, 50; Specint92, 62.3; Specfp92, 66.5	Two MIPS R4400, one expandable to 24	IRIX	Cache: internal, 32 KB; external, 1 MB RAM: 64 MB (16 GB)	Internal, 2 GB (32 GB)	Color, 21-inch, 1600 x 1200	E, SCSI, SCSI 2, parallel, serial (FDDI)	—

N.A. = Not available from the vendor.
1. MIPS = millions of instructions per second; Mflops = millions of floating-point operations per second.
2. Terms in parentheses indicate options offered by vendors. 3. Cache and RAM sizes given in bytes. 4. Disk storage given in bytes.
5. E = Ethernet; IBIM = intelligent bus interface module; ISDN = Integrated-services digital network; TR = token ring; SCSI = small computer systems interface; FDDI = fiber distributed data interface.
6. CD ROM = compact-disc ROM; EISA = extended industry standard architecture; IDE =interactive data entry; DAT = digital audio tape.

front end of the graphics pipeline, being turned into pixels, which must then be written into a frame buffer. Finally it is scanned out to video to appear on a monitor, projector, or virtual-reality head-mounted display.

Graphics performance benchmarking must thus embrace a combination of CPU, memory, bus, geometric, pixel, and video operations, all in a balanced system architecture. A bottleneck in the graphics pipeline at any stage will reduce the overall performance substantially, suggesting that just like the observations made during the Perfect Benchmark tests, no single metric tells the whole story.

GRAPHICS SPECIFICATIONS. The feature sets of the general-purpose graphics systems currently on the market vary at least as much as their performance specifications. Still, Table 2 identifies, as far as feasible, a common ground for comparison. To that end, all assumptions are stated explicitly.

As the table indicates, general-purpose computer graphics systems are usually compared using benchmark numbers for generating quantities of vectors, points, and polygons, as well as those for pixel fill rates, displayable resolutions, and other operations. Some attempts have been made at standardizing these benchmarks, so as to make apples-to-apples comparisons between systems easier.

Since benchmarks so rarely reflect the performance attainable in actuality, it is necessary to weigh their results in a context of both quantitative and qualitative information about the specified systems. Table 2 lists each of the compared performance metrics and how they are specified. A single metric is used for uniformity across all of the graphics systems, with the exceptions called out in footnotes.

While these metrics will be useful for comparison, they fail to reflect differences in either the system architectures or the graphics subsystems. Benchmarks tend to test a single metric at a time, with few mode changes, like changing the color every 100 polygons or applying different texture maps to every 50 polygons. But real applications change modes frequently, starting and stopping the flow of data, so that they rarely achieve the performance that is quoted in benchmarks.

The ways in which vendors may quote specifications are listed in Table 2, with exceptions identified in the footnotes as before. One system may seem superior on some benchmarks while another may do better on some other tests. This difference occurs because no two graphics systems make the same performance tradeoffs, which may be subtle and undocumented. The tradeoffs may only come to light during the running of a benchmark that stresses the graphics system in the way in which it will be used. To be useful, more often than not, graphics benchmarks must be derived from (or at least be very like) real applications.

REAL APPLICATIONS. With increasing frequency, workstations are being used for scientific and engineering problems in which both advanced computational and graphics capability are required to obtain and understand the solution. Such areas as computational chemistry and structures, geo-

tational chemistry and structures, geophysics, and industrial design are by now heavily dependent on having both capabilities. As a result, there are already applications in those areas that can be used to benchmark the performance of systems. Still, those from different areas exercise systems in different ways. So it is worth looking at several areas to see what their applications can tell about a workstation's abilities.

Applications for computational chemistry and molecular modeling are advancing every year. The early programs required little more than large quantities of anti-aliased vectors for stick-figure molecules. Today's software tends to be more complex, combining polygonal "spheres" and "cylinders" with isosurfaces (surfaces on which a common value occurs) and selective transparency, as well as clipping planes to cut into the molecules for cross-sectional views.

In the area of computational structures, the demands of finite-element analysis for both stress/strain and fluid-flow analysis are such as to require very complex surfaces to be rendered if the part or structure being analyzed is to be accurately represented. Surfaces are usually divided into pieces that represent the atomic level at which the analysis is performed. Once the analysis is complete, each piece, or its vertex, is assigned a value representing the result of the analysis for that location for a particular time and set of parameters.

The parameters for the rendered surface are represented by a wide range of attributes, possibly a different attribute at each vertex of every geometric primitive. This results in a complex mode change that may well disrupt the efficiency of the rendering process. Such applications test how well a system's graphics pipeline is balanced.

In geophysics and geographical information system (GIS) applications, two elements are primary: volume rendering and image processing. Geophysical applications take raw and postprocessed data and visually render it to simplify comprehension and analysis. A representation may be based on volumetric data from seismic surveys and core samples, as well as on geometric data from isosurfaces extracted from within the strata being studied.

With the goal of providing access to information about a specific location, GIS applications apply images of that location to geometric representations of the region, and then combine that data with other, non-image data. The representation may be made up of vectors, polygons, and text indicating parameters applicable to the area. It may include such information as flood planes, roadways, power lines, seismic activity, and the demographics of residents and businesses. Such geophysical applications test a system's texture-mapping and volume-generation capabilities, as well as its ability to produce high-resolution displays of real image data.

The creation of realistic images from design data is the forte of industrial product designers. They use computer systems for the design and manufacture of products ranging from wrist watches to automobiles, employing software tools such as Alias Studio from Alias Research Inc., Toronto, to create 3-D images for pre-prototype evaluation. This kind of software requires a high degree of interactivity, and tests a system's ability in the areas of Tmesh, independent, and environment-mapped polygons.

The last kind of polygon resembles the texture-mapped type, except that the texture exists in space surrounding the polygon. Objects constructed with such polygons reflect the environment in which they are placed. They are critical for representing objects such as automobiles with glossy paint and glass.

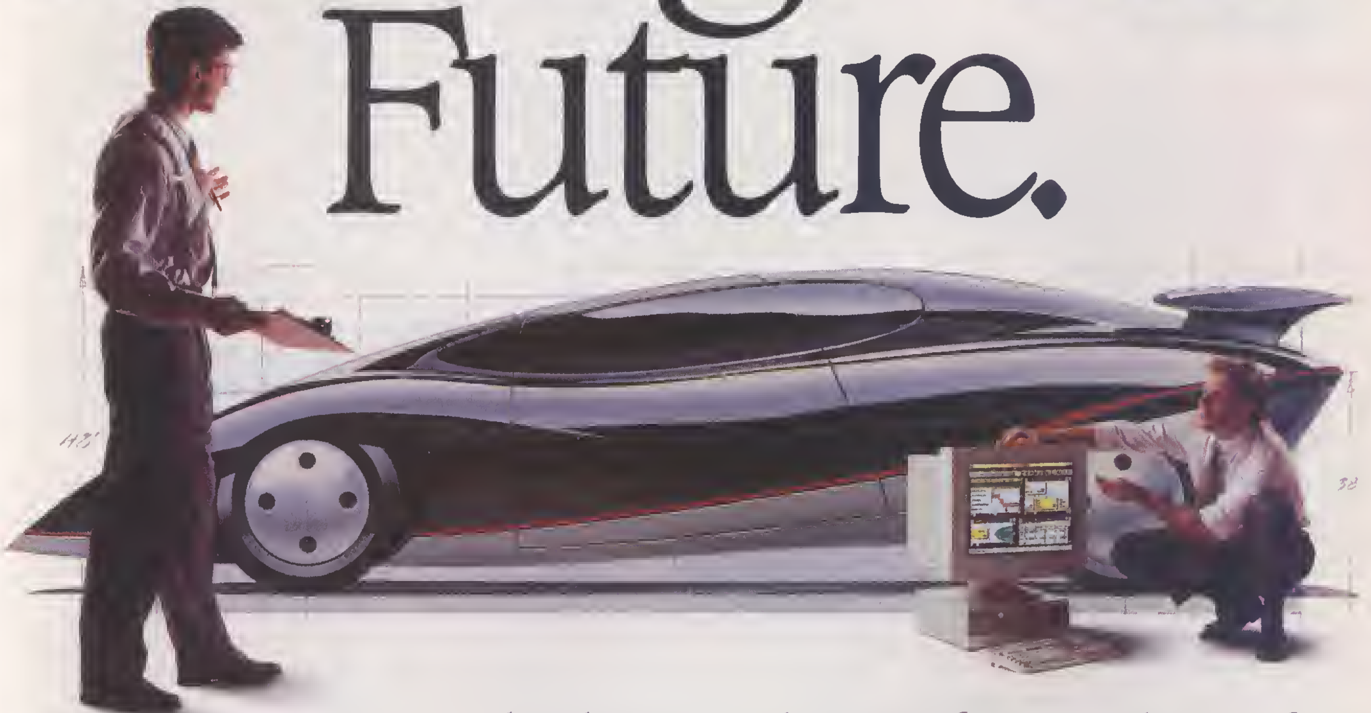
The applications that lay the heaviest demands on systems, however, are those generally classified as scientific visualization. Because of the nature of this type of work, it is not possible to know in advance exactly what types of features or performance metrics will be critical. When visualizing multidimensional data, scientists may look at a wide range of data types, including 2- and 3-D geometric data, 2-D image sampled data, 3-D volume sampled data, N-dimensional array data, and more.

DRAWING CONCLUSIONS. To the benefit of the computer consumer at any level, therefore, there are a wide variety of advanced benchmarks and benchmarking suites that can run on just about every computer being manufactured today (at least in the United States and Germany). The perplexing thing is how to identify which of them is meaningful in the context of how the system will ultimately be used. For those planning to run a particular type of application—such as molecular modeling, CAD/CAM (computer-aided design and manufacturing), finite-element analysis, or image processing—it is always best to use existing benchmarks based upon that type of application. If none exists, ask the vendors under consideration to run a special benchmark that stresses the system in the same sort of way as would the designated application.

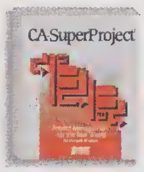
For users expecting to perform a variety of functions or who expect that the computer system will serve a variety of users, the benchmarking suites are a good place to start. But as indicated earlier, factors such as the amount of memory and disk in the system can dramatically change the overall performance of the system, and must therefore be taken into consideration. All in all, benchmarks offer some good guidelines about certain aspects of system performance, but should be used only with a good understanding of their capabilities and limitations.

ABOUT THE AUTHOR. Joshua Mogal (M) is product manager, advanced systems, for the Computer Systems Division of Silicon Graphics Inc. in Mountain View, Calif. ◆

How To Manage The Future.



The Ultimate Combination Of Power And Ease-Of-Use. Now Available For Both Windows *And* OS/2.



Introducing the first project manager your entire company can use.

For power users, there are dozens of new features, functions and an internal development language that makes creating advanced macros quick and easy.

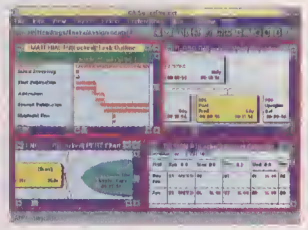
For beginners, the easiest, friendliest interface and shortest learning curve in the industry.

The new graphics and reporting options will make every user look like a genius. And since it runs under Windows and OS/2, you won't be burning any bridges.

1992 W 100 WINDOWS MAGAZINE ANNUAL WIN AWARD

MICROSOFT. WINDOWS. COMPATIBLE

Buy one version, get the other FREE.



FOR A FREE DEMO DISK CALL
1-800 CALL CAI EXT. 240.

Free Demo Disk

Call today to test-drive the award-wining project management software that can help you manage the future.

Today.

COMPUTER ASSOCIATES®
Software superior by design.

New CA-SuperProject 3.0.

Circle No. 212

X, as in expediency

X terminals can help a network of widely dispersed workstations ensure the most efficient use of its computing power

All the people do not use all the power of all a company's computers all of the time. Utilization of this idle power is what makes X terminals so valuable, and why organizations are adopting them in droves.

Indeed, the X Window System has received "near catholic acceptance among technical applications and users," according to Stephen Auditore, president of the X Business Group, a Fremont, Calif., consulting firm, as it is finding widespread use in nontechnical industries as well. His company's research indicates that the market for X products and services grew by more than 60 percent in 1992, to US $820 million. It also shows that nearly half a million X terminals are in use today. That means there is roughly one X terminal for every two X-compatible workstations, or one for each X-compatible PC.

These less expensive terminals deserve their desktop spot beside their costlier partners for a good reason. They concentrate on the human side of computing. Their function is not to provide the resources needed for complex computations, but rather those for fast and effective transfer of information between the user and the system.

There is a restriction: applications employed by an X terminal user must support the open X standard of the X Consortium at the Massachusetts Institute of Technology, Cambridge. (As of this writing, the current version of the X standard is X11 Release 5.) But, as many applications do support X, users are likely to find one that suits them.

The X standard defines how a so-called display server controls communication between the user's mouse or keyboard and the application and, conversely, between the application and display windows. Applications communicate with the display server using calls to the Xlib, a library of C-language subroutines, which resides with the application in the host system. The Xlib in turn employs the X-wire protocol to communicate display information to the display server.

Richard Comerford Senior Editor

Although information display is an essential function of X terminals, the X standard does not specify any one graphic user interface (GUI). Instead, it lets GUIs be built on top of the X standard with the help of a tool kit, a style guide, and a window manager. A tool kit is a set of high-level subroutines for generating menus, scroll bars, push buttons, and other basic elements of a GUI, dubbed widgets. The style guide is a set of rules that explains how the application should react to the user's manipulation of widgets; it describes the "look and feel" portion of the GUI. The window manager controls the interface elements in accordance with another set of rules that specify the allowable sizes and positions of windows and widgets.

Tool kits and window managers are distributed with the X window standard, but they are there to serve as samples of what such kits and managers should do, and are not really a part of the standard. Thus X systems may support GUIs ranging through the Open System Foundation's Motif, Sun Microsystems' OpenLook, Digital Equipment's DECWindows, Hewlett-Packard's New Wave, Microsoft's Windows, and others. As for traditional computer terminal displays, the standard supports them with a terminal emulation program.

What's more, the X standard defines a mechanism for incorporating extensions, so that new terminals can add features without becoming incompatible with existing systems. This mechanism has allowed the consortium (through a subcontract with Sun Microsystems Inc., Mountain View, Calif.) to add PEX—extensions based on the Phigs and Phigs Plus. Phigs—the programmer's hierarchical interactive graphics system—is a graphics library used to display and interact with three-dimensional images. As a library standardized by the International Organization for Standards, it provides portability of 3-D graphics between many different computer operating systems and GUIs. Phigs Plus (where Plus is an acronym for "plus *lumière und* surfaces," emphasizing the standard's international leitmotiv) was approved by the ISO in 1991 and adds definitions for lighting, shading, and other advanced graphic operations to Phigs.

SELECTION CRITERIA. These days, money does not just talk, it screams. So just how does the price of an X terminal compare with that of network-ready PCs or workstations? For the same size of screen and input device, an X terminal will cost half as much as a low-end desktop computer, and as monitor size rises, so does the price ratio.

Because the X Window System has become so popular, almost any workstation today can serve as host to an X terminal. As noted earlier, there is already a slew of applications that work with the X system, but cautious buyers will want to check with their application vendors just to be on the safe side.

In fact, one of the pleasures of buying X terminals is that there are relatively few criteria to consider. First, there is the matter of the display. X terminals offer color or black-and-white and, if the latter is preferred, a choice of gray-scale or monochrome. As with workstations, display diagonals run from 14 to 21 inches, and resolutions go from 1024 by 768 picture elements up through 1024 by 1024 pixels to 1152 by 900. In choosing display size and resolution, the most important consideration is consistency with the other workstation displays. The mouse and keyboard options should be as rich as those offered for workstations.

Determination of graphics performance—how quickly the terminal can paint the screen with text and graphics—is much the same as for workstations, and Xstones, a suite of display applications, are a popular benchmark here. Performance is one of the things a buyer pays for, and typical performance measurements range from more than 50 000 to over 100 000 Xstones.

An X terminal's internal dynamic RAM should be large enough to support whichever GUIs will be used. As these interfaces may change, it is useful to be able to upgrade memory in the field.

In the communication area, no standard exists to date to determine how well an X terminal will perform, so users may want to fly before they buy. Unlike the timeshared host of the 1970s, workstation hosts are not likely to be burdened by serving X terminals, provided the workstation does not have to do a lot of paging. Users will want to be sure that the host has enough RAM for local applications plus that needed for the terminal applications.

Do not worry that X terminals will saturate the network bandwidth. X terminal communications are bursty and usually require only small data packets (typically 100–200 bytes), which makes them ideal for Ethernet environments. Still, the X standard is network independent, so an X terminal is at liberty to support a wide variety of networks: Ethernet, token ring, the Integrated-Services Digital Network (ISDN), and so forth. ◆

0018-9235/93/$3.00©1993 IEEE

X terminals: a representative sample of those available

Performance ratings	Central processing unit[1]	Operating systems supported	Floating-point accelerator	Dynamic RAM[1,2]	Monitor[1]	Interfaces[1,3]	Other features and options[3]
Color							
C.Itoh Technology, CIT-XE, US $2827, 5 days							
Xstones: 60k	TI 34020 and 340 X (optional processor)	Partial CIT-XE; AIX, Sun OS, HP 9000, SGI, DEC	N.A.	4 MB (36 MB), 70 ns	21-inch 1280 x 1024 (17-inch, 1280 x 1024)	Thick E; BNC; parallel; serial	Unix-like kernel allows full process control, ease of networking, and remote diagnostics
Hewlett-Packard Co., HP 700/RX 19 Ca, $4995, 2 weeks							
Xstones: 93k	Intel i960	SCO ODT, AIX, Sun OS, HP 9000 series 800 and 700	On CPU chip	4 MB (18 MB)	19-inch, 1280 x 1024	Thick E; BNC; parallel; serial	—
Human Designed Systems Inc., Viewstation FX 19Ci, $1699, 30 days							
N.A.	Intel i960	Unix, Sun OS, VMS, DOS, AIX, Mac	On CPU chip	4 MB (68 MB), 70 ns	19-inch, 1280 x 1024 (several sizes, resolutions)	Thin, thick, and twisted-pair E; parallel; serial	IBM, DEC, Sun, 3270, multinational keyboards; mouse or trackball
Jupiter Systems, MX600, $6500, 30 days							
Xstones: 80k	Intel i960	N.A.	On CPU chip	4 MB (128 MB), 80 ns	19-inch, 1280 x 1024	E, parallel (2nd E, SCSI 2)	Hardware pan, zoom standard; options include up to six color monitors and hard-disk drive
Network Computing Devices Inc., MCX17, $4295 , 30 days							
Xstones: 100k	Motorola 88100; three ASICs for graphics	Any compatible with X Window system protocols	On CPU chip	6 MB (68 MB), 80 ns	17-inch (up to 1152 x 900)	Choice of three E; serial (TR)	Audio support; cable security cover; wide range of keyboards; 3270 and VF320 local clients; local window manager
Phase X Systems Inc., PX19CA2, $3495, 4 weeks							
Xstones: 56k	AMD 29000	Unix, VMS, Ultrix	None	4 MB (16 MB), 70 ns	19-inch, 1280 x 1024	Thin and thick E; serial (twisted-pair E)	One-year warranty; hotline support; two-day service; options include Sun or DEC keyboard
Tektronix Inc., XP338, $5995, 4 weeks							
Xstones: 105k	MIPS R3000; TMS34020 graphics	Unix, VMS, Ultrix, AIX, Sun OS, HP 9000, SGI	None	5 MB (32 MB)	19-inch, 1280 x 1024	Choice of two E; two serial	Options include IBM PS2, DEC VT200, or Sun keyboard and optimization kits for DEC, Sun
Grayscale/monochrome							
Hewlett-Packard Co., HP 700/RX 19 Ga, $3495, 2 weeks							
Xstones: 93k	Intel i960	SCO ODT, AIX, Sun OS, HP 9000 series 800 and 700	On CPU chip	4 MB (18 MB)	Grayscale, 19-inch, 1280 x 1024	Thick E; BNC; serial; parallel	—
Human Designed Systems Inc., Viewstation FX19, $1699, 30 days							
N.A.	Intel i960	Unix, Sun OS,VMS, DOS, AIX, Mac	On CPU chip	4 MB (68 MB), 70 ns; internal flash PROM, 2 MB	19-inch, 1280 x 1024 (several sizes, resolutions)	Thin, thick, and twisted-pair E; parallel; serial	IBM, DEC, Sun, 3270 multinational keyboards; mouse or trackball
Network Computing Devices Inc., NCD19r, $2895, 5 days							
Xstones: 88k	MIPS R3000; ASIC for graphics	Any compatible with X Window system protocols	N.A.	4 MB (20 MB)	19-inch 1280 x 1024	Choice of three E; TR; serial	3270 and VF320 local clients; local window manager; non-glare screen; wide range of keyboards
Phase X Systems Inc., PX19M, $1495, 4 weeks							
Xstones: 77k	AMD 29000	Unix, VMS, Ultrix	None	3 MB (18 MB), 70 ns	19-inch, 1280 x 1024	Thin and thick E; serial (twisted-pair E)	One-year warranty; hotline support; two-day service; options include Sun or DEC keyboard
Tektronix Inc., XP11, $995, 4 weeks							
Xstones: 72k	TMS 34020; two ASICs for graphics	Unix, VMS, Ultrix, AIX, Sun OS, HP 9000, SGI	None	4 MB (12 MB)	15-inch, 1024 x 768	Thin, thick, and twisted-pair E (two serial)	Options include IBM PS2, DEC VT200, or Sun keyboard and optimization kits for DEC, Sun

N.A. = not available from the vendor.
1 Terms in parentheses indicate options offered by vendors.
2 Optional RAM sizes in parentheses are maxima.
3 E = Ethernet; TR = token ring; SCSI = small computer systems interface.

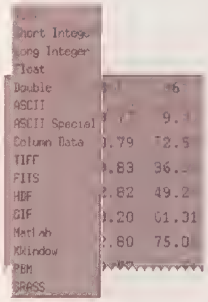
The Quickest Tool for Analyzing Data and Images

NEW! Spyglass® Transform 3.0

- Labeling • Animations • Scripting language
- Direct import of many new data types
- Same features for UNIX and Macintosh versions

MATHLINK
This Product Connects To Mathematica®

Whether you work with numerical matrices, spreadsheet data, or satellite images, Spyglass Transform makes data analysis faster and more effective. Use Spyglass Transform alone for analysis and presentation, or use it for a quick snapshot of your data before using visualization or computational environments. An intuitive user interface lets you do it all with **absolutely no programming!**

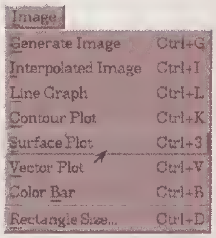


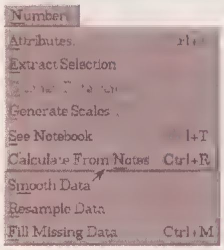
Just Click...

...to import virtually any data or image file format, including ASCII, binary, TIFF, FITS, HDF, GIF, MatLab®, XWindow, PBM, GRASS and others. Your data appears instantly in a spreadsheet display that works interactively with the images and plots you generate from the data.

Just Click...

...to create color raster images, contour plots, vector plots, surface plots, and line graphs. Compare multiple images and datasets, and generate animations. Overlay plots for composite graphics. Select from the 20+ supplied color tables or import new tables. Add titles, labels, and tick marks for presentations. Print out any image or plot.

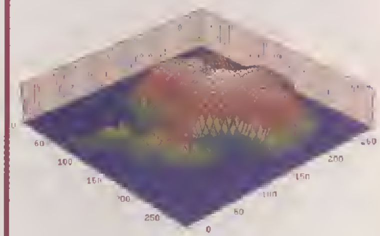




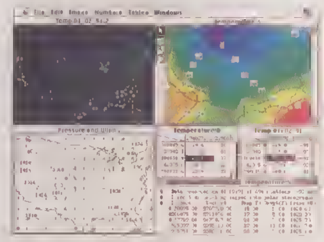
Just Click...

...to use built-in manipulation functions and kernel convolutions, as well as mathematical, trigonometric, and statistical functions, or call external custom functions. Make macros to perform identical operations on different datasets. Smooth and resample data arrays by a variety of methods, and fill missing values. Export data and images to other programs.

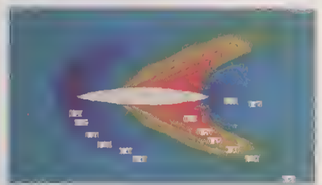
Join the thousands of scientists and engineers who use Spyglass Transform



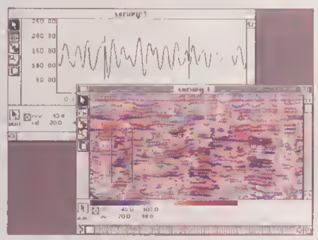
Surface elevation of Antarctica
Data: Professor Doug MacAyeal, Univ. of Chicago



U.S. Weather, January 2, 1991
Data: University of Illinois at Urbana-Champaign Dept. of Atmospheric Sciences



Simulation of wind flow over an airfoil at Mach 0.5
Data: Dr. Mark Christon, Lawrence Livermore Labs



Slice from 3D seismic survey
Data: Halliburton Geophysical Services, Inc.

Special Offer on Spyglass Transform and Mathematica

Spyglass Transform 3.0 supports MathLink, allowing you to send arrays and Transform commands from within Mathematica—now it's easy to visualize Mathematica-generated functions as plots and images in Transform. To mark the connection of these two superb software products, Spyglass is offering a special price when you buy Transform and Mathematica together. Call 1-800-647-2201 for details.

SPYGLASS

1-800-647-2201

- Macintosh $595
- UNIX (Floating license—Sun, IBM, HP, DEC, SGI) $995

Spyglass, Inc., 1800 Woodfield Dr., Savoy, IL 61874 tel: (217) 355-6000 fax: (217) 355-8925 or—Australia: MacScience 03 499 2607; France: RITME 4246 0042; Germany: SW Design 024 08 60 71, Vistec 06112 2037; Japan: IMI 03 365 3641, Sumisho Electronics 03 5228 5621; Netherlands: IVS 02263 53707; Spain: AddLink Software Cientifico 320 731 58; Taiwan: Hitron Technology 02 2983456; UK: Adept 0462 480 055

Circle No. 214

Of workstations & supercomputers

Figuring out which of the two types of machine best suits a problem requires constant attention as both classes continue to evolve

One of the more heated topics in high-performance computing circles today is the evolving relationship between supercomputers and workstations. When supercomputers were new, users typically got access to them through mainframes. Later, as workstations grew in popularity and power, they became the most usual supercomputer front-end. Now, the emergence of more powerful workstations—especially workstation-based clusters and multiprocessor configurations, has spurred a debate about the future of the alliance.

Most industry observers agree that the basic alliance will continue because workstations and supercomputers remain complementary. Advances in hardware and standards-compliant software have made it possible to exploit the combined capabilities of networked supercomputers and workstations in a way that is largely transparent to the user [see "Microscopy at a distance," p. 68]. For the foreseeable future, any direct competition between combinations of workstations, on the one hand, and supercomputers, on the other, will probably be confined to the low end of the supercomputer market—systems priced at US $300 000 to $1 million, which were once called minisupercomputers and now go by the name of entry-level systems.

The performance improvements of single-chip microprocessor technology have been impressive, but have not led to the replacement of current-generation supercomputers by lesser machines. In the two cases to date where companies claimed their workstation clusters replaced a supercomputer for some applications, the systems in question were 1982-era Cray Research machines—equivalent in performance and market value to today's entry-level supercomputers.

This demonstrates yet again a longstanding computer industry reality: the performance boundaries of all classes of systems are constantly advancing. While workstation products now easily handle some problems done on past-generation supercomputers, supercomputers have evolved to tackle problems that were once intractable. PCs can now handle some tasks that required workstations only a few years ago.

CATEGORIZING APPLICATIONS. The real problem is to define the networked computing resource best suited for a particular application. Clearly, many applications have always been more appropriate for workstations than supercomputers; and with the advent of more powerful microprocessors, the scope of workstation-class applications has increased dramatically.

Five or six years ago, for example, even the simplest structural analysis (linear static analysis) of a model, involving 10 000 degrees of freedom, required a supercomputer. Today, productive engineering on models of that size and complexity can be done on high-end workstations, running the same structural analysis programs formerly regarded as suitable only for supercomputers—Ansys, Abaqus, and MSC/Nastran, for example.

But during this same period, supercomputers have scaled structural analysis simulation into an entirely new range—starting at 250 000 degrees of freedom and extending to millions of degrees. Problems using ANSYS, an I/O-intensive structural analysis program, have run on the 16-processor CRAY C916, for example, at sustained speeds of 6–7 billion floating-point operations per second (gigaflops).

What this and similar examples indicate is that the ranges for workstation-class and supercomputer-class problems are advancing concurrently as both types of systems become more powerful. As a result, the essential division of labor between workstations and supercomputers remains intact.

Parallel vector supercomputers—and, less extensively to date, systems of massively parallel processors (MPPs)—are used to solve problems that are too large, too complex, or too time-critical to tackle on workstations or workstation-based configurations. Shorter time-to-solution is, of course, more than just a user convenience. The ability to simulate large-scale problems more quickly, hence also to perform more iterations in a given timeframe, can be a critical competitive issue affecting time to market.

CATEGORIZING COMPUTERS. As a framework for discussing problem domains, it is useful to consider what each computing resource on the network is and does best. This analysis employs sustained floating-point performance to distinguish among classes of computers, since theoretical peak performance claims are of little value in real computing situations.

PCs are generally priced below $3000 and deliver floating-point performance of less than 10 megaflops, unless specialized add-in boards are employed.

Workstations satisfy needs similar to those of PCs, but are generally quite a bit faster (5–50 megaflops) and have a more sophisticated system organization. Workstations generally range in price from $5000 to $50 000, although high-end workstations with specialized capablities can cost more than $100 000.

Servers include multiprocessor workstations, workstation clusters, mainframes, and entry-level supercomputers (parallel vector processors or MPPs). Prices range from $100 000 to well over $1 million. Floating-point performance is generally well

1. Requirements and resources

Functional requirements	Resources: PCs and workstations	Servers (mid-range)	Super-computers
User interface • Low complexity • Fast interaction (seconds) • Visualization	Transparency	–	–
Capacity • Middle complexity • Medium turnaround time (minutes) • High throughput	Throughput	Throughput	Throughput
Capability • High complexity • Long turnaround time (hours) • Mission success	–	–	Complexity ÷ time

Worlton and Associates

Mark Furtney Cray Research
George Taylor Sun Microsystems

0018-9235/93/$3.00©1993 IEEE

Computational complexity of some technical problems, in number of computer operations required

[1] The computational complexity of technical problems varies over an enormous range. Even if attention is restricted to large-scale problems, the complexity (in operations required) spans a range of 10^{14}:1.

under 1000 megaflops, although high-end servers can approach that level. The workstation cluster, a relative newcomer to the server class, is a collection of workstations on a network, loosely coupled as a "metacomputer." The coupled machines collaborate on problem-solving, using a communications mechanism such as a message-passing library or distributed shared memory.

The advantages of entry-level supercomputers are several: moderate costs in comparison with larger machines, compatibility with a large set of supercomputer applications, and compatible scalability with more powerful supercomputers as problems grow in size or complexity.

Supercomputers may be parallel vector systems or MPP machines. Sustained floating-point performance on supercomputer-class sytems begins at about 1000 Mflops (1 Gflops). Prices for this class of system typically extend from about $1 million to $30 million or more.

The most powerful current supercomputers have sustained 5 Gflops or more on some full application codes. In the 1992 Gordon Bell Prize contest, the highest-performing MPP system sustained 5.4 Gflops on an application. The top-of-the-line CRAY C916 system from Cray Research Inc., Eagan, Minn., has sustained 10–12 Gflops on a number of full third-party applications.

THE NEED FOR SPEED. One of the forces driving performance in computers is the desire on the part of most users for applications that respond interactively. The delay that users of all types of computers are willing to endure until a computer responds seems to be lessening as time goes on. These users want answers to existing problems more quickly than before, and they want to be able to tackle new problems that time or size constraints previously made intractable.

As computer performance improves, more problems become solvable interactively by a given class of machine. Nonetheless, a problem will always fall into one of three categories: interactive-class, capacity-class, and capability-class [Table 1].

Interactive-class problems are those that are solved in essentially real time on all but the lowest-end computers. Any application that relies principally on a graphical user interface is in this class; the business productivity applications typically run on PCs, such as word processors, spreadsheets, and graphical illustration programs are the most familiar examples.

Fast workstations have allowed computer-aided-design (CAD) packages to enter the interactive class. It is now possible to use a workstation to perform interactive logic and circuit simulation for IC design and to perform animated architectural walk-throughs of buildings that are still under design.

Capacity-class problems are those that any class of computer system can solve, but with markedly different throughput rates. A system's throughput on capacity-class problems is directly related to its sustainable compute power. The type of computer system most appropriate for capacity-class problems depends on the circumstances—how much throughput is required to maintain user productivity in a given situation. A capacity calculation that takes 15 minutes to complete on a workstation will usually be done on a workstation, since this does not seriously disrupt productivity.

A problem that would remove a workstation from use for 12 hours, however, might require other options. If time-to-solution is not critical and the problem is not too large, it can be solved overnight on a workstation. But if solution time is important, the calculation typically is assigned to a higher-throughput server or supercomputer on the network.

Capability-class problems are tractable only because of supercomputers. These problems are both complex and time-critical. Problems that are complex but not time-critical can be run on an entry-level supercomputer or some mid-range computers. The same holds for problems that are time-critical but not so complex.

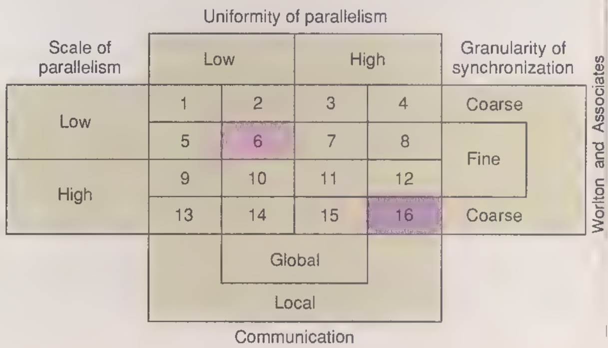
Consider, for example, a medium-scale application with a total complexity of 10^{12} operations, such as problems in chemistry, turbulence, or visual simulation [Fig. 1]. A workstation running in the range of 10^7 to 10^8 operations per second would take 10^4 to 10^5 seconds—a few hours to a day—to solve the problem. The user's schedule might make this entirely satisfactory.

If the solution were more time-critical, though, then a server with an execution rate of 10^8 to 10^9 operations per second could achieve the result in half an hour to a few hours; or a supercomputer with a (sustained) rate of 10^9 to 10^{10} operations per second would take only a few minutes.

Really large problems today have complexities on the order of 10^{15} operations. For a supercomputer-class calculation like this, a workstation would need a runtime of 10^7 to 10^8 seconds—one to three years—to complete a single instance of the problem. Parameter studies, in which hundreds or thousands of runs are made to produce a profile of the solution space, could take decades. Workstation clusters might reduce these times, provided the problem mapped well onto their loosely coupled processor organization. But the solution time on a multiprocessor workstation, workstation cluster, or entry-level supercomputer would still be unacceptable to most users.

ANALYZING APPLICATIONS. In sum, the class of a problem is directly related to the type of

(Continued on p. 68)



[2] Computer applications can be usefully classified on the basis of four main attributes: degree of parallelism, uniformity of parallelism, granularity of synchronization, and communications.

Servers: a representative sample of those available

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory				Monitor[2]	Interfaces[2, 5]	Other features and options[6]
			Main[2, 3]	Hard drive[2]	Tape backup[4]	CD ROM[4]			
Low end (under $10 000)									
CompuAdd Computer Corp., CompuAdd MC 466EDX Tower, $4729–$17 000, varies									
MIPS: 26.33; Landmark: 222.91; Norton 5.0: 127.8	Intel i486 DX2/66	MS DOS 5.0, MS Windows 3.1 (Unix Interactive Systems, OS/2 2.0)	Cache: internal, 8 KB; external, 64–256 KB RAM: 4–256 MB, 80 ns	Internal: 500 MB, SCSI (4.1 GB) External: N.A.	O	O	Color: 14-inch, 640 x 480 pixels (monochrome: 14-inch, 600 x 800 pixels)	C, two RS-232C serial ports (E, TR, SCSI, SCSI 2)	Upgradable with future Intel Pentium-based OverDrive processors; flash BIOS for updating via software, 4-hour response on-site service in major metropolitan areas; 5 internal and 4 external drive bays
Dell Computer Corp., Dell 466SE/DSA, $7994–$19 000, 10 days									
N.A.	Intel i486 DX2/66	MS DOS 5.0, MS Windows 3.1 (Unix SVR4, OS/2 1.21)	Cache: internal, 8 KB; extl., 128 KB, 14 ns RAM: 8–128 MB, 80 ns	Internal: 1 GB (7 GB) External: 57 GB total	O	O	Color: 14-inch, 1024 x 768	SCSI 2, C (E, TR)	—
Laser Digital Inc., Pacer Vesa 486–50 Multimedia Server, $4475, 7 days									
MIPS: 22; Power Meter V:17	Intel i486 DX/50	MS DOS 5.0, MS Windows 3.1 NT	Cache: intl., N.A.; external, 64–256 KB, 20 ns RAM: 4–128	Internal: 200 MB (650 MB) External: N.A.	O	S	Color: 14-inch, 1024 x 768 (color: 17-inch, user options)	SCSI 2, C (E, TR, Arcnet)	CD-ROM, 16-bit stereo Media Concept Pro Sound card, 2 external speakers, full-size microphone
Mobius Computer Corp., Protege Series, Model P466is, $6220–$7000, 7–10 days, ARO									
MIPS: 40; Xstones: 15K (Super VGA)	N.A.	Unix (Choice of SCO/ODT, Interactive Systems, or Unix Ware)	Cache: internal, N.A.; external, 252–512 KB RAM: 8–128 MB, 70 ns	Internal: 535 MB, (1.21 GB) External: 4 GB	O	O	Color: 14-inch, 1024 x 728 (17-inch, 1280 x 1024)	E, SCSI, SCSI 2, C	—
Sun Microsystems Computer Corp., SPARCclassic Server, $5295, 5–10 days									
MIPS: 59.1; Mflops: 4.6; Specint92: 26.4; Specfp92: 21.0	TI Micro SPARC 50-MHz RISC	Solaris 2.x	Cache: internal, 6 KB (2 KB data, 4 KB instr.); external, N.A. RAM: 16–96 MB, 60 ns	Internal: 1 GB, SCSI External: 22 GB, SCSI	O	O	Mono: 19-inch, 1152 x 900 (color: 15-inch, 1000 x 768; 16-, 19-inch, both 1152 x 900)	E, SCSI 2, C (TR, Fast SCSI, buffered Ethernet, FDDI, HSI)	—
Unisys Corp., PW2 Advantage Plus Model 4668, $5443–$6553, immediate									
N.A.	Intel i486 DX2/66	(SCO Unix, MS DOS 5.0, MS Windows 3.1, OS/2 1.2, Novell Netware)	Cache: internal, 8 KB; external, 256 KB RAM: 8–128 MB, 80 ns	Internal: 525 MB (1 GB) External: N.A.	O	O	(Color: 14-inch, 1068 x 768)	SCSI 2, C, two serial ports, UPS signal port (E, TR)	Upgradable to Intel Pentium (with 64-bit data path)
Mid-range ($10 000–$45 000)									
Data General Corp., DG4625, $27 995, 20 days ARO									
MIPS: 78; AIM: 591; Specint92: 1097.9	Dual 88100	DC/UC	Cache: 192 KB RAM: 32 MB (128 MB)	Internal: 520 MB (1.9 GB) External: 58 GB	S	O	N.A.	N.A.	N.A.
Hewlett-Packard Co., HP 9000 Server 800 Model 640, $30 000, 4–6 weeks									
MIPS: 68.9; Mflops: 20; Specint92: 50.5; Specfp92: 81.6; TPC-A: 74.93 (Informix)	HP PA 7000	HP-UX	Cache: internal, N.A.; external, 256 KB RAM: 32–512 MB, 80 ns	Internal; 566 MB (6 GB) External: 100.4 GB	S	O	Mono	E, SCSI 2 (TR, C)	—

Performance ratings[1]	Central processing unit	Operating systems[2]	Memory: Main[2, 3]	Memory: Hard drive[2]	Memory: Tape backup[4]	Memory: CD ROM[4]	Monitor[2]	Interfaces[2, 5]	Other features and options[6]
Intergraph, InterServe 2700, $12 500, N.A.									
MIPS: 68.2; Specint92: 24.5; Specfp92: 35.8	Intergraph Clipper C400	Unix SVR3	Cache. 16 KB RAM: 32–128 MB, 80 ns	Internal: 1 GB External: 8.4 GB	O	O	N.A.	E, SCSI, serial port, Versatec (TR)	—
Sun Microsystems Computer Corp., SPARCServer 10, Model 41, $16 995 (minimum)									
MIPS: 109.5; Mflops: 22.4; SPECint92: 53.2; SPECfp92: 63.4	SPARC Version 8	Solaris 1.1, 2.1	Cache: intl., 16–20 KB; extl., 1 MB Super-Cache RAM: 32–512 MB	Internal: 424 MB, SCSI 2 External: 41 GB	O	O	N.A.	E, ISDN, SCSI 2 (TR, Audio Port)	—
Unisys, U 6000/65, $24,000–$175,000, 30 days									
MIPS: 47; TPC-A: 75 (Informix)	From one (std.) to five Unisys U 6000/65 CISC units	Unix SVR4.0 MP	Cache: intl., 8 KB, 20 ns; extl., 1 MB, 20 ns RAM: 16–256 MB, 80 ns	Internal: 1 GB (4 GB) External: 44 GB	S	O	(Color or mono,14-inch)	SCSI, C (E, TR, ISDN)	—
High end (over $45 000)									
Auspex Systems Inc., NS 5500, $125 000–$600 000, 30 days									
NSF IOPS: 1703	4 (10) Sparc processors	SunOS 4.1	I/O cache: 16–96 MB RAM: 20–68 MB	Internal: 2.0 GB (40 GB) External: 120 GB total	O	S	Mono: 15-inch X-terminal	E, SCSI	—
Data General Corp., Aviion AV 6280, $199 000–$2 000 000, 20 Days, ARO									
MIPS: 235; TPC-A: 239.1; TPC-B: 316.83; Specint92: 3245.0; AIM users: 1665	Eight 88100s	DB/UX 5.4.2	Cache: 5 MB RAM: 256–768 MB, 90 ns	Internal: 1.4 GB (4.2 GB) External: 320 GB)	S	S	N.A.	SCSI 2 (E, C, sync, async)	Can be configured with one or more disk arrays providing RAID (levels 0, 1, 3, 5), redundant coding systems, power supplies, and controllers for nearly fault-tolerant performance
Hewlett-Packard, HP 9000 Server 800 G50, $49 000, 6 weeks									
MIPS: 106; Mflops: 30.9; Specint92: 75.2; Specfp91: 141.6	PA 7100	HP-UX	Cache: internal, N.A.; external, 256 KB RAM: 32–768 MB, 80 ns	Internal: 566MB (6 GB) External: 100.4 GB	S	O	Mono	E, SCSI 2 (TR, C)	—
Intergraph, InterServe 6809, $73 900, N.A.									
MIPS: 85; Mflops: 16.3; Specint92:3: 6.1; Specfp92: 65.6	Clipper C400	Unix SVR3	Cache: intl., 16 KB data, 16 KB instr.; extl., N.A. RAM: 64–512 MB, 60 ns	Internal: 4.2 GB (60 GB+) External: N.A.	S	S	N.A.	E,SCSI 2, Versatec, FDDI, Serial, X.25 (TR)	Fast Quad SCSI standard
Sun Microsystems Computer Corp., Sparccenter 2000, $95 000, 60 days									
MIPS: 2.1; Mflops: 269; Specfp92: 10 600	2–20 Super Sparc processors	Solaris 2.X	Cache: intl., 16 KB (36 KB); extl., 1 MB per CPU, 20 ns RAM: 69 MB–5 GB, 100 ns	Internal: 4.26 GB (386 GB) External: 17 GB	S	S	(Mono or color, 19-inch, 1152 x 900)	E, SCSI, SCSI 2 (TR, ISDN, C)	—

N.A. = not available from the vendor.
1. MIPS = millions of instructions per second; Mflops = millions of floating-point operations per second.
2. Terms in parentheses indicate options offered by vendors.
3. Specified times are cache and RAM access times.
4. O = optional; S = standard.
5. C = Centronics (parallel) port; E = Ethernet; FOOI = fiber distributed data interface; ISON = integrated-services digital network; TR = token ring; SCSI = small computer systems interface.
6. BIOS = built-in operating system; CD ROM = compact-disc ROM; RAIO = redundant array of independent discs.

(Continued from p. 65)
system that can best solve the problem. Another way of looking at this is to analyze the attributes of various applications. Figure 2 provides a taxonomy of applications based on four key application attributes: scale (degree) of parallelism, uniformity of parallelism, granularity of synchronization, and communications. For simplicity, each of the four attributes is shown with only two values; in reality, each attribute constitutes a continuum.

An application's scale of parallelism corresponds to the number of processors that could be kept busy if an unlimited number of processors were available. Uniformity of parallelism is the uniform average of the scale of parallelism as a function of time. An application has coarse-grain synchronization if there are many operations between synchronization points; it is fine grained if the number of these operations is small. Local communications occur across single links to which a node is directly connected; global communications occur across multiple links.

Ideal applications for parallel computation would fall into category 16—high degree of parallelism, high uniformity of parallelism, only coarse-grain synchronization, and only local communications. Applications in this category are likely to run well on computer systems of all kinds. Some examples in this category are Gaussian, Spartan, Cadpac, LSDyna, and Disco (petroleum industry).

The most difficult applications for effective parallel computation, conversely, are those that fall into category 6—low degree of parallelism, low uniformity of parallelism, fine-grain synchronization, and global communications. This category of applications typically will not run well on workstation clusters or MPP systems and includes Nastran, Ansys, and Fluent.

WHERE WORKSTATIONS WORK. The interconnection networks for loosely coupled workstation clusters have long latencies and low communications bandwidths in comparison with tightly coupled supercomputers. Hence, workstation clusters are best at solving problems having very coarse-grain synchronization and communications requirements—meaning that a huge proportion of the problem involves computation, and a minute amount of synchronization and communication is needed. An example of such an application is rendering frames from a computer-animated movie: each frame may be assigned to a separate workstation in the cluster. Communication occurs only when frames are started and finished.

As some workstation clusters evolve from loosely coupled multicomputer systems to more tightly coupled multiprocessor systems, they become almost indistinguishable from low-end MPP systems—and face most, if not all, of the same basic challenges. These include applications conversion for medium- or large-scale parallel computation, developing strong parallel compilers, and substantial hardware redesign to enlarge interconnect and memory bandwidths.

Powerful networking, having been pioneered and proven over the past decade, is by now taken for granted by most users. Workstations and supercomputers were the first disparate computing resources to be widely networked, and currently, the networking revolution is trickling down into the PC market as well.

In the early 1980s, Cray Research became the first supercomputer firm to move to a Unix-based operating system. This step led to easy, transparent interaction with workstations from a variety of leading vendors. In January 1992, the growing importance of the supercomputer-workstation link led Cray Research and Sun Microsystems Inc., Mountain View, Calif., to enter into a formal agreement to create an integrated software environment for application development and deployment. Cray Research is also using Sun technology to build high-end Sparc-based computers through the company's Cray Research Superservers (CRS) subsidiary.

Ideally, vendors will create a *homogeneous* distributed processing environment in which a given application may be run on each networked resource. In such an environment, an engineer might produce low-resolution, wire-frame proofs of an animated multimedia presentation of a new engine on a workstation. When the proofs were deemed ready, the engineer could develop a full-resolution, solid-form, ray-traced version of the engine on the networked supercomputer without necessarily being a computer networking expert.

In heterogeneous distributed processing, by contrast, the computing resources are not architecturally compatible, and distributing an application across both resources generally requires greater user sophistication and intervention.

ABOUT THE AUTHORS. Mark Furtney is a senior networking expert at Cray Research Inc., Eagan, Minn., where he has been heavily involved in parallel vector and massively parallel processor systems. George Taylor is director of microprocessor development at Sun Microsystems Inc., Mountain View, Calif. His interests include processor architecture, computer arithmetic, and biCMOS design. ◆

Microscopy at a distance

A good example of how supercomputers and workstations work together is a pioneering medical research project involving the University of California at San Diego Microscopy and Imaging Resource, the San Diego Supercomputer Center, and The Scripps Research Institute.

The project, now under way, is aimed at making the microscopy and imaging resource's 400 000-V transmission electron microscope accessible to researchers nationwide through high-speed digital communications networks. That goal mirrors the direction of the Federal government's High Performance Computing and Communications (HPCC) program. Not surprisingly, therefore, a gigabit-per-second National Research and Education Network is being developed around the San Diego medical research project under HPCC auspices.

Normally, in electron microscopy work, a researcher sits at the microscope and records various views of a tissue sample for later comparison. At the microscopy and imaging resource in contrast, the researchers may be located away from the microscope. They sit at workstations linked to a prototype capture/control workstation. Built around Sun Sparcstation 2 units, it transfers on-line control of the microscope to the remote users.

Graphical interfaces on the remote workstations interact with the capture/control workstation and, when necessary (for compute-intensive three-dimensional reconstructions), with the supercomputer center's Cray Y-MP8 and the Scripps Institute's Cray Y-MP2E systems.

When a researcher requests an animation, for instance, the capture/control workstation collects a "tilt series" of 60 two-dimensional images from the microscope. These images are aligned and pre-processed by the capture/control workstation, then sent to an application, called Suprim, that runs on the supercomputer. There Suprim aligns and back-projects the images to produce a volumetric (three-dimensional) dataset. Working with that dataset, the supercomputer center's NetV software renders images from 72 viewing positions in a 360 degree rotation. The resulting animation is sent to the remote workstation and added to the image database.

This environment gives the remote researcher control of the electron microscope's stage position and magnification with nearly on-site efficiency. A microscope operator performs tasks, like focusing, that cannot yet be done remotely.

The electron microscope is being used in new areas of biomedical science such as: the breakdown of nerve cell components due to Alzheimer's disease; the structural relations of protein molecules involved in releasing calcium within neurons; and the 3-D organization of the Golgi apparatus, where sugars are added to proteins.

The 3-D animations or stereo views help researchers to see, for example, minute differences between a normal brain cell and one from a patient with Alzheimer's disease.

Computer control and automation have the potential to make the electron microscope available to any researcher on the Internet. The ultimate benefit of this pioneering collaboration will be new drugs and therapies for treating the full spectrum of health threats.

—*Phil Cohen, Mark Ellisman, Phil Mercurio*

Phil Cohen is director for research and computing at The Scripps Research Institute; Mark Ellisman is staff physician and director of the San Diego Microscopy and Imaging Resource at the UCSD School of Medicine; Phil Mercurio is staff programmer analyst at the San Diego Supercomputer Center.

New peripherals increase options

A survey of recent offerings for PCs and workstations indicates that users will have more choices than ever—at more reasonable prices

The crossover of personal computer and workstation markets has started a whole new ball game in the peripherals arena. Vendors who once thought only in terms of providing for PC systems are now eyeing workstations, while their workstation counterparts are taking note of PCs.

From this interaction, four developments seem to be emerging. One is that, as the distinction between workstation and PC systems fades, more players are taking part in the various peripheral markets, and the pressure to reduce prices has intensified.

Another is the onset of bus wars, leading to increased connectivity options. Because of the wars, peripheral makers hoping to keep pace with the growing competition between workstations and PCs are having to scramble to keep up with the variety of buses and ports now in use.

A third development is the new set of approaches being used for storage needs, brought on by greater use of visualization techniques and the need for more flexibility in handling the many new system configurations. And finally, new technical capabilities are cropping up as technologies invented to solve a specific problem wind up meeting a collection of varied needs.

SLASHED. Sliding prices are part of the turf in high technology, as chips continue to become more capable at lower cost. There is no reason to expect prices in the peripherals markets to do anything but drop as long as workstations continue to become less expensive.

John King Contributing Editor

For instance, CalComp Inc., to make room for its Drawingmaster Professional plotters, lopped as much as US $3000 off the 200-dot-per-inch models in its DrawingMaster Plus series. Another product, the Amdek AM/817 17-inch monitor from Wyse Technology Inc., lists for 12 percent less than it did last year.

Western Digital Corp., which markets to original-equipment manufacturers (OEMs), is charging a single-unit price of only $700 for its Caviar AC2420, a 420-MB, 2.5-cm-high, 3.5-inch hard-disk drive. Meanwhile, Iomega Corp. has just knocked 10–20 percent off what it is asking for its Tape250 minicartridges, and has trotted out a new Tape250 that connects to PCs via the parallel port.

KEEP CONNECTING. Staying current on the latest offerings of buses and ports is keeping peripheral makers hopping. "The thing to watch for in the peripherals market is bus standards, how people are going to connect," comments Terry Bennett, director of Technical Systems Research for Infocorp, a Beaverton, Ore., market research firm. Noting that Digital Equipment Corp., Maynard, Mass., abandoned third-party hardware development for its recently developed Turbochannel high-performance bus, Bennett suggests it was "an admission that the world just didn't need one more standard."

Among the most popular buses in the workstation world are Sun Microsystems Inc.'s Sbus, the VMEbus developed by the VMEbus International Trade Association, and IBM Corp.'s Micro Channel Architecture (MCA) bus, which is also used in its PS/2 series of PCs. The Sbus is used in Sun's Sparcstations and Sparc clones, which together are beginning to dominate the workstation market. The older VMEbus is used in earlier Sun workstations and has a large installed base of devices. In the past few years, the VME group has developed Futurebus+ in an attempt to establish one standard.


StereoGraphics Corp.

CrystalEyes VR from StereoGraphics Corp. is a virtual-reality interface for workstations. Wearing liquid-crystal–shutter eyeglasses, a user manipulates stereo objects with a 3-D mouse; a screentop unit senses the viewing angle from the position of the glasses.

Meanwhile, to bridge the growing bus gap between the Sbus and VMEbus, one company that markets both peripherals and systems, Solflower Computer Inc., San Jose, Calif., is offering a series of workstations that includes both VMEbus and Sbus capability. For those who already have Sparcstations, Solflower offers external Sbus-to-VMEbus adapters.

A company taking sides, though, is Concurrent Computer Corp., Oceanport, N.J. It is snubbing the Sbus in favor of dual VMEbus support in the high-end Series 7000 workstations. But Analyx Systems Inc. is siding with Sbus. The company makes the ADDA-1418 Sbus data acquisition and control board for Sun Sparcstations and compatibles. Designed for scientific, medical, and industrial applications, the isolated ADDA-1418 subsystem can simultaneously acquire and output data without real-time intervention by the central processor.

Joel Libove, vice president for R&D at Analyx Systems, is confident that reliance on Sbus will pay big dividends. "Based on developments I've seen in the past year," he claimed, "Sun and its

0018-9235/93/$3.00©1993IEEE

clones are going to take over the workstation marketplace." Further, Libove foresees a shakeout in the PC industry that would leave only platforms based on Intel Corp.'s Pentium processor standing and make a clash between Pentium and Sparcstations inevitable.

While awaiting that potential Armageddon, the PC industry itself is in the throes of a deepening bus war for IBM and compatible systems. Two 32-bit-wide buses, the Extended Industry Standard Architecture (EISA) and IBM Corp.'s MCA are up against two 16-bit buses, the older Industry Standard Architecture (ISA) and the emerging 16-bit PCMCIA2. But these input/output buses, which run at 8 MHz, have not kept pace with the speed of current central processing units (CPUs), running at 33 to 50 MHz. Local buses, which connect peripherals directly to the CPU, are now challenging them.

GRAPHICS NEEDS. Fueling the need to make full use of today's faster processors are the demands of graphics applications. Proponents of the local bus say the capability it brings to PCs allows them to compete with graphics workstations.

Two chief standards are going head to head in the local bus department: the 32-bit-wide VESA local-bus (VL-bus) from the Video Electronics Standards Association (VESA) and Intel's 64-bit Peripheral Component Interconnect (PCI) bus for its 486 and coming Pentium chips. Products based on the PCI bus will start coming out in the next few months, but it remains to be seen if PCI can dislodge the early market lead of VL, which already has products (mostly graphics adapters) on the market. Right now there are about twice as many vendors lined up behind VL.

Currently popular PC ports and standards include the old familiar serial and parallel slots as well as the small computer systems interface (SCSI).

Peripheral suppliers wishing to cover all bets are offering many options, especially for input, output, and storage devices. Vendors are not only crossing over between workstations and PCs, but between system brands as well.

Among the newer products is the Tektronix Phaser printer, which offers parallel, serial, and Appletalk support along with a DECnet interface option. The PS7800 SCSI disk-drive subsystem from Parity Systems Inc. is compatible with Sun Microsystems, Silicon Graphics, Digital Equipment, IBM RS/6000, and HP 9000 systems.

Macintosh and IBM PC support are offered by the Wyse WY-270 monitor and by Pinnacle Micro's PMO-130 optical drive, which also supports Sun and Silicon Graphics workstations. Kurta Corp. offers an XGT Serial Graphics Digitizing Tablet that runs with Macintosh, PC, and Sun machines.

For large-scale and multi-user configurations, Falcon Systems Inc. has introduced its FalconRAID storage system. (RAID stands for redundant array of inexpensive disks.) The company claims the new system is platform independent because it can be installed on a Unix workstation or a centralized, networked file/compute server that is connected to SCSI or SCSI-2 peripheral devices.

Major storage player Iomega Corp. offers an external subsystem containing two 150-MB drives with optional interface kits for Sun, DEC, NeXT, HP-Apollo, and Silicon Graphics workstations.

Leading workstation manufacturers are doing some gap bridging of their own. Digital and Silicon Graphics Inc. recently joined Hewlett-Packard Co. in providing EISA buses in their workstations, thereby allowing them to take in PC peripherals.

STORAGE METHODS. Workstation users have always needed a lot of storage for graphic images—a need now reflected in the business market, with the growing use of multimedia technology. While the voraciousness of visualization techniques for data continues to increase storage needs, a range of new applications and system configurations are requiring storage devices to have greater flexibility. These demands are causing a clash of storage technologies in

(Continued on p. 75)

Add-on boards and peripherals for workstations: a representative sample

Company	Product	When first available	Unit cost, US $	Key features and comments[1]
Hardware accelerators and coprocessors				
Alacron Inc.	FT860/2-V	4/92	$9000–$13 795	One or two 50-MHz i860 processors; optional daughter boards include SCSI, DT-Connect, Visionbus, memory expansion, HRG (true-color frame buffer), DI (to camera)
Avalon Computer Systems Inc.	Vaccelerator AP/40	1/93	$9990	100-MIPS, VAX/VMS-compatible coprocessor intended for compute-bound applications on VAX and MicroVAX systems; recompile-and-run simplicity of use
Computer System Architects	Super Set Ultra	10/92	$29 315	Multiuser parallel processor provides spatial partitioning of processors and up to 16 simultaneous users
CSP Inc.	SC-3XL/VME	1/93	$16 000 (with 8-MB memory)	Vector processor includes one 50-MHz i860 (200 Mflops); up to 64-MB DRAM and 200-MB/s I/O; SuperKit and multiprocessor software
DayStar Digital Inc.	33-MHz Turbo 040	12/92	$1599	68040 accelerator for Macintosh IIsi, IIvi, IIvx, IIci, II, IIx, IIcx, SE/30; Performa 600; compatible with System 7 features and Quadra software; turbo expansion slot
Fusion Data Systems	TokaMac II	4/92	$2595 (IIfx); $1895 (IIci)	33-MHz 68040 accelerator for Macintosh; 128-KB cache; plugs into processor direct slot (PDS) with connection to Nubus
Kingston Technical Corp.	MicroMaster 486	5/92	$915 (486 SX 25-MHz); $1395 (486 DX 33-MHz)	Upgrades 286 and 386 PS/2s to 486; supports up to 16 MB of 32-bit RAM on-board
Microstar Laboratories Inc.	DAP 3200e data-acquisition processor	1/93	$3495	On-board i486 processor and real-time multitasking operating system; plugs into 286/386/486 PC platforms running Windows, DOS, or OS/2
Opus Systems	Sparcard 2	3/92	$3995	Adds Sparcstation-2 capability to ISA/EISA PCs; from single PC, user can access both DOS and Unix applications
SKY Computers Inc.	Skybolt-mp Shamrock	6/92	$102 700	Sixteen i860 processors on one 9U VMEbus board deliver 1.28 Gflops; i960 processor on motherboard performs system functions, allows i860s to be dedicated to computing
TransEra Corp.	Make-it 486	11/92	$299	Upgrades 286-based systems to 486 at double clock speed; 2–4 times increase in application speed; runs any 32-bit software; compatible with all motherboards, including notebooks and laptops
Digital signal processing boards				
Analogic Corp.	HEXC31 array processor	2/93	$12 995	240-Mflops compute power; 16-MB memory
Ariel Corp.	V-C40 Hydra	8/92	$9995–$36 495	Single-slot 6U VMEbus board with 24-bit parallel expansion bus, 200 Mflops, 1.1 billion operations per second; four TMS320C40 DSP processors
Atlanta Signal Processors Inc.	Banshee II	10/92	$3895	Compatible with Banshee board; uses true dual-port memory for TMS320C30-to-host communications
Datacube Inc.	Max 860	3/92	$15 900	RISC pipeline image processing to support full-frame and region-of-interest processing
Data Translation Inc.	DT3809 single-board test and measurement system	8/92	$7495	Total test, measure, and processing system; single PC board with embedded TMS320C40 chip enables mixed-signal synthesis and capture
Spectral Innovations Inc.	MacDSP MB/A	6/92	$3495	Single-board DSP system complete with AT&T DSP 32C and Motorola 68000 analog I/O capabilities
Spectrum Signal Processing Inc.	TMS320 C40 dual processor 600-01515	9/92	$7295	IBM PC/AT-compatible board for parallel processing and parallel DSP; each board supports two MDC40S DSP modules based on Texas Instruments' TIM-40 specification
Symmetric Research	DSP MUL	10/92	$1400	Four 50-MHz, 32-bit DSP32Cs; 100 Mflops; includes software
Valley Technologies Inc.	ULTRADSP	2/93	$22 000	6U VMEbus board performs large FFTs 10 to 20 times faster than i860- or C40-based DSP boards; lowest latency of any Sharp LH9124-based VME board; compatible digitizer and buffer board set
Storage and backup systems				
Memory boards				
Dataram Corp.	DR475 memory for Sun Sparcstation 2 and IPX	6/92	$2400–$4800	Backward-compatible with Sparcstation 2 and Sparcserver 2 models; expands Sparc 2 and IPX systems to 128 MB
Helios Systems	Helios Sparc 10 16-MB and 64-MB memory upgrade	11/92	$595–$5100	Lifetime warranty, 100% Sun-compatible
Tecmar Inc.	Microram 386	2/93	$490	32-MB RAM; 32-bit
Valley Technologies Inc.	Ultrabuffer	2/93	$9000	6U VMEbus memory board for high-speed data acquisition; fully compatible with ULTRADSP board; can directly interface with 8 of company's 40-MHz 10-bit digitizers

Add-on boards and peripherals for workstations: a representative sample *(continued)*

Company	Product	When first available	Unit cost, US $	Key features and comments[1]
Storage and backup systems *(continued)*				
Magnetic-disk drives				
Acropolis Systems Inc.	2.0 GB, 3.5 SCSI Fast Disk Subsystem ASI-38-1600	2/93	$2595	10-ms seek time, 5400 rpm; 1.6-GB formatted capacity; compact desktop configuration
Conner Peripherals Inc.	Aegean and Bajan Series 3.5-inch	2/93	$700	545 MB with 10-ms seek time, 43.1-MB/s data transfer rate; 1.37 GB with 10-ms seek time, 45.8-MB/s data transfer rate
Core International Inc.	LAN Array	2/93	$15 495 (2 GB) $19 995 (4 GB)	Fault-tolerant disk array; hot pluggable drives; redundant power supply
Iomega Corp.	Floptical PC Powered	11/92	$399	Second-generation 21-MB, 3.5-inch floptical drive for IBM PCs and compatibles
Maximum Strategy Inc.	Strategy Gen 4 Storage Solutions	9/92	$202 500–$475 000	Programmable RAID-level partitioning including levels 1, 3, and 5; supports 800/s I/Os and transfer rates as high as 90 MB/s for high-performance computing
Maxtor Corp.	Maxtor MXT-540	10/92	N.A.	One-inch-high, 3.5-inch, 540-MB drive; average seek time of 8.5 ms
Mega Drive Systems Inc.	MR/RAID	2/93	$15 000	Fault-tolerant, high-performance, fully redundant, massively parallel arrays; up to 1 terabyte
Mountain Network Solutions Inc.	File Safe Sidecar Parallel Port tape drive	1/93	$695	Connects to host system via the parallel port; 305 MB of storage per DC2120 cartridge
Parity Systems Inc.	PS7800 series subsystem	7/92	$1975–$6553	Up to 5 GB stored on four 3.5-inch full-height Winchester disk drives; SCSI-2 interface; 10-ms average access time
Procom Technology Inc.	MTD 2900	1/93	$8495	SCSI-2 drive with 10-MB/s maximum data transfer rate; 11-ms seek time, 512-KB cache
Quantum Corp.	ProDrive LPS 525 S/AT	10/92	$1169	525-MB, 3.5-inch hard drive; embedded SCSI-2 or IDE-AT interface; 10-ms seek time; 512-KB cache buffer
Syquest Technology	Syquest SQ 3105 removable cartridge disk drive	12/92	N.A.	IDE compatible; uses 105-MB cartridge; 14.5-ms average seek time; 100 000-hour MTBF
Western Digital Corp.	Caviar WDAC2420	2/93	$700	Two platter, 420-MB hard drive; under 12-ms access time
CD ROMs				
Laser Magnetic Storage International Co.	CM 206 double-speed CD-ROM drive	3/93	$499	Drive spins disk at twice normal speed; transfers data over 16-bit AT bus; photo CD compatible; motorized tray
NEC Technologies Inc.	MultiSpin 74 (External)/84 (Internal)	2/93	$615 (74); $550 (84)	300-KB/s data transfer rate; Kodak photo CD multisession compatible
Sony Computer Peripheral Products Co.	Sony double-speed CD-ROM drive/CDU-561	6/93	N. A.	300-KB/s sustained transfer rate; photo CD multisession compatible
Optical drives				
Cygnet Systems Inc.	Series 1800 Expandable Jukebox family	3/93	$45 000–$85 000	Compatible with 12-inch optical-disc drives; certified reliability of 425 000 media exchanges
Fujitsu Computer Products of America	Fujitsu M2511A magneto-optical	10/92`	$1700	One-inch-high; 3600 rpm; fixed optics; embedded SCSI controller
Laser Magnetic Storage International Co.	LF 4502 Rapid Changer	3/92	$68 000	56-GB total user capacity; 11.2-GB on-line capacity
Literal Corp.	525GB+	1/92	$3999	5.25-inch WORM with 640-MB capacity per side
Pinnacle Micro Inc.	PMO-130	1/93	$1695–$1995	Uses 3.5-inch rewritable disk; 128 MB of storage; 19-ms effective access time; available for PC, Mac, and Sun
Plasmon Data Systems Inc.	RF-7010 multi-function optical-disk drive	4/92	$3995	Accepts both write-once and erasable optical-disc media; utilizes next-generation phase-change erasable technology

Company	Product	When first available	Unit cost, US $	Key features and comments[1]
Sony Computer Peripheral Products Co.	Sony WDD-931	6/92	$30 000	Stores up to 6.55 GB on each 12-inch write-once optical disc; 900-KB/s data transfer rate
Magnetic-tape systems				
Falcon Systems Inc.	Falcon RAID	2/93	$29 000 and up	Independent platform (no new hardware/software needed to connect to Unix workstation); 3.5- or 5.25-inch drives swappable without powering down
GigaTrend Inc.	MasterDat Lite	10/92	$3350	Workstation-based backup; 5.0 GB of unattended backup storage
Sony Corp. of America	SDT-4000	7/92	N.A.	4mm digital data storage (DDS) tape drive can store 8.0 GB of compressed data; sustained data transfer rate of up to 732 KB /s
Spectra Logic	STL-8000 automated library	5/92	$27 680	Capacity for forty 8mm tapes stores up to 200 GB; menu-driven LCD front control panel
Tallgrass Technologies Corp.	FS10G	12/92	$8995 (internal); $9495 (extl.)	Hardware data compression from tape drive in a 5.25-inch half-height form factor with 60-MB/minute data transfer and 10-GB capacity
Tecmar Inc.	Data Vault 4x4	2/93	$8995	16-GB storage, 22-MB minimum backup/restore speed
Wangtek Inc.	Netware Ready QIC-525 MB and QIC-1.0 GB	2/93	$1995 and $2195	Complete server-based backup with N LM Software for Netware
Input devices				
Digitizer tablets				
GTCO Corp.	Ultima 1212	1/93	$399	Standard 16-button cursor; clear sensor on cursor eliminates coil to provide unobstructed view
Hitachi America Ltd.	HDG-1212E	1/92	$449	Real- and protected-mode ADI drivers; mouse emulation
Kurta Corp.	XGT Serial	10/92	$600	Runs on Mac, IBM PC and compatibles, and Sun; screen and tablet scaling; 256 pressure levels; pens sold as options
Kye International Corp.	Genius Hisketch 1212	1/93	$429	Slim-line design, software, Autosketch and Microsoft Windows pen extensions, four-button cursor, two-key ballpoint stylus
Numonics Corp.	GraphicMaster II	7/92	$595	User-configurable softkeys allow one-touch tablet configuration changes; audible feedback for softkey activation, and setup menu selection
Science Accessories Corp.	GP-10 Sonic	6/92	$1775	Totally programmable output formats emulate any digitizer; 6-by-25-inch footprint; digitizing area 30 by 36 inches; RS-232 output
Wacom Technology Corp.	SD-510C Pro Set	7/93	$795 (suggested retail price)	6-by-9-inch (active area) Wacom tablet with SP-310 soft-type, pressure-sensitive, cordless, batteryless stylus and SC-510 cordless, batteryless 4-button cursor
Light pens				
FTG Data Systems	Pen direct for Mac, Model FT-1272	1/93	$498	Offers direct, onscreen input for Mac II, LC, and Quadra computers; compatible with Systems 6.5 and 7.x
Track balls				
Logitech Inc.	Trackman II	4/92	$139	Three-button ergonomic design; programmable
Micro Speed Inc.	Win Trac PD 930	3/93	$149	Trackwheel for third analog input; automatic personality change between applications
Stereo Graphics Corp.	CrystalEyes VR	12/92	$3995	Combines Logitech's 3D Mouse and HeadTracker with Stereographics' Crystal Eyes; for Sun Sparcstation 2GT
Output and display				
Graphics adapters				
ATI Technologies Inc.	Graphic Ultra Pro	6/92	$599 (1 MB VRAM); $799 (2 MB VRAM); $899 (EISA/ISA, 2 MB)	1280 x 1024 x 256 color noninterlaced resolution; full acceleration at 1024 x 768 x 65 000 colors; multimedia video ready
Edge Technology Inc.	VL24 Bitblaster	2/93	$199	GUI accelerator supports VESA local-bus specification (VL-bus); 2-MB RAM; 24-bit true color (16.8 million colors)
Evans & Sutherland Computer Corp.	Freedom Series 1000 and 3000	10/92	$25 500+	Standard antialiased lines; hardware-supported texture mapping

Add-on boards and peripherals for workstations: a representative sample *(continued)*

Company	Product	When first available	Unit cost, US $	Key features and comments[1]
Output and display *(continued)*				
RGB Spectrum	Watchdog 150	1/93	$5995–$9995	Up to 15 video windows on a computer display
Univision Technologies	Piranha Series/ UDC7000-TI	4/92	$2495	Resolutions from 1024 x 1024 to 1600 x 1200; 8, 12, 24, and 32 bits per pixel
High-resolution monitors				
Amdek	Amdek AM/817	1/92	$1139	17-inch color display with a 0.26-mm dot pitch; resolutions up to 1280 x 1024 at 72 Hz
Sony Peripheral Products Co.	Sony GDM-2038 Trinitron Multiscan	2/93	$3795.95	Refresh rate: 80 Hz at 1280 x 1024 noninterlaced resolution; full digital control of settings, including color temperature
Wyse Technology Inc.	Wyse WY-870	2/93	$1149	1280 x 1024 noninterlaced resolution; microprocessor-based digital controls
Other displays				
RGB Spectrum	RGB/Videolink 1500A	2/93	$11 995	Full-screen conversion to video; auto-sync for all workstations, PCs, and Mac IIs
Graphics printers and pen plotters				
CalComp Inc.	CalComp Classic	12/92	$6995	E-size pen plotter; multicolor; eight pens; cut-sheet or roll feed; 1-MB buffer; serial and parallel interfaces; LAN interface option
Fujitsu Computer Products of America	DL5800 dot-matrix printer	1/92	$1995	630-character/s draft speed; 48-character LCD
QMS Inc.	QMS 860 print system	9/92	$4595	Standard connections to parallel, serial, local talk; optional Ethernet (Ether Talk, Netware, TCP/IP and DECnet) or Token-Ring (Netware) connection; 600 x 800 dots per inch
Tektronix Inc.	Phaser 200i/e PostScript Level 2 thermal wax color printer	1/93	$5995 (200i); $3695 (200e)	Plain paper; two pages per minute, 300 dots per inch
Communication and controls				
I/O boards				
Analyx Systems Inc.	ADDA-1418	3/92	$1995–$2495	Data acquisition and control board fully contained in workstation; automatic sampling and outputing
IOtech Inc.	DaqBook/100	2/93	$1295	Attaches to notebook or PC parallel port; 8 differential or 16 single-ended analog inputs, expandable to 256; two 12-bit DA converters
Loughborough Sound Images Ltd.	DPC/C40B	8/92	$4445	Modular parallel signal-processing capability; flexible, modular, real-time I/O capability
National Instruments Corp.	AT-MIO-16X	9/92	$1995	16-bit sampling AD converter with 16 analog inputs; two 12-bit DA converters with voltage outputs
Interface boards				
Barr Systems Inc.	T1-SYNC	2/93	$700	Synchronous adapter up to 2.0 MB/s; includes RS-232, V.24, V.35, X.21, and RS-530 interfaces
Helios Systems	Helios Com+	2/92	$995	V.32Bis (14 440 b/s); S bus internal
IOtech	SCSI 488/H	8/92	$1495	SCSI-to-IEEE 488 conversion for control of up to 14 IEEE 488 devices; 1-MB/s data transfer
Infinicon	Infinistor	1/93	$199–$299	Gives controlling PC direct access to storage devices of a dedicated PC; transparent once PCs are booted up
Keithley Data Acquisition	KPC 488.2TM	2/93	$750	IEEE-488 interface with trigger master; increases test throughput up to 8 times while preserving full programmable control
Loughborough Sound Images Ltd.	PC/DMCB	11/92	$895+	Carrier board forming part of company's flexible, modular I/O range for its LSI DSP boards on the PC AT
National Instruments Corp.	GPIB-ENET/Sun	5/92	$1595–$2695	Removes distance limitation set by IEEE 488.1 standard; shares GPIB peripherals among many networked users
Local-area network (LAN) boards				
Ansel Communications	All-in-one Ethernet Model 3200	8/92	$399	32-bit EISA Ethernet combination adapter for high-speed graphic workstations; up to 400 percent higher performance with Unix
Interphase Corp.	S/EDDI 4611 SunBird	3/92	$1795–$1295	Single attachment; Sun O/S driver with integrated SMT; installation guides; media attachment available for fiber, STP, or UTP
Milan Technology Corp.	Fast Port	3/92	$699	Network print server; Novell and Unix

1 DSP = digital signal processing; (E)ISA = (extended) industry standard architecture; Mflops = million floating-point operations per second; MIPS = million instructions per second; MTBF = mean time between failures; RISC = reduced-instruction-set computer; SCSI = small computer system interface; TCP/IP = Transmission Control Protocol/Internet Protocol; WORM = write once, read mainly.

(Continued from p. 70)
two arenas: networks with file servers, and single-user configurations.

Traditionally, tape and cartridge storage systems have provided most backup needs, including those of networks. However, desire for greater backup capacity is evidenced by the entry of RAID technology, once reserved for supercomputers and mainframes, into the PC and workstation market. Maximum Strategy Inc., which markets primarily to IBM Corp., Cray Research Inc., and other OEMs, as well as to the highest-end end-users, reports that RAID technology, now in its fourth generation, is also invading Unix-based workstation and PC networks.

Billed as the world's fastest form of storage, the Gen 4 RAID technology, using Maximum Strategy's High-Performance Parallel Interface (Hippi) card, can transfer data at 100 megabytes per second. Meanwhile, the FalconRAID system for workstations offers capacities as high as one terabyte.

Contending with RAID are CD ROM (which also has a place in single-user systems), optical "jukebox" storage, and high-end magnetic tape or disk.

At last year's PC Expo, Sony Corp.'s Computer Peripherals Products Co., Park Ridge, N.J., showed off its CDU-561 CD-ROM drive, which doubled the data transfer rate of previous Sony drives to 300 kilobytes per second while boasting an access time of 300 milliseconds.

In the emerging market for recordable CD ROM (so called despite the inherent contradiction between "recordable" and "read-only" memory), Pinnacle Micro offers 5.25-inch drives for DOS and Mac systems. Each of the disks can hold 580 MB, which makes them good candidates for backup storage.

Price is an important factor in these offerings. The RCD-202 for the Mac retails for $3995; the PC version is $4195. Average random seek time is 300 ms; write time is 600 ms. Tape drives cannot compete with those numbers, but the jury is still out as to whether the recordable CD ROMs can launch a serious challenge to the dominant tape backup technology.

The "jukebox" optical storage concept, in which optical platters are contained in a box much like records in a jukebox, is not new, but Pinnacle Micro is making the technology more "manageable" by offering file management software with its systems. They support all current Sun architectures, including Sun-4, Sparcstations, Sparcservers, and the Sparc 600MP. Software is also available for Mac environments.

Though it is delving into some new technologies, Iomega is far from abandoning the traditional magnetic field. Since late last year the company has been introducing models in its Bernoulli MultiDisk family of 150-MB drives for DOS machines, and for Apple's Quadra, Centris 650, Performa 600, and Macintosh IIvx.

One of the newest technologies being employed by Iomega is floptical storage—a hybrid of magnetic and optical storage. This could confound the potential showdown between those two technologies in the single-user market.

But displacing advanced magnetic storage products will be hard. Consider Maxtor Corp.'s MXT-540, 2.5-cm-high, 3.5-inch drive, whose average seek time of 8.5 ms is attractive to high-end PCs and low-end workstations. By way of comparison, a 3.5-inch optical drive designed for a lower-end market has an access time of 19 ms while a floptical drive has one of 65 ms. Compared with traditional magnetic floppy-disk storage, however, floptical and optical drives are much faster.

By entering the same performance ballpark as the magnetic hard drives they compete against, optical drives could make significant inroads into market share. Using removable media, the optical drives require a higher initial investment but offer two key advantages when compared to magnetic ones: a lower cost per megabyte and a storage capacity limited only by the number of disks used.

Iomega, which can afford to take some

risks, now offers second-generation floptical drives, which provide an alternative to, and mix of, both the magnetic and optical worlds. Floptical technology combines magnetic recording on flexible magnetic media with optical tracking. Magnetic recording ensures downward compatibility with existing magnetic floppy disks, while optical tracking enables greater speed and more storage. Meant for the general PC market, Iomega's floptical drive can connect to ISA, EISA, and MCA buses as well as to Macintosh Quadra systems. It has a storage capacity of 21 MB, making it a good choice for backing up hard drives.

Thanks to its optical tracking servo, floptical technology can achieve a track density of 1245 tracks per inch, compared with 135 tpi for magnetic floppies. It may do even better when Iomega's patented holographic technique proves out. That technique calls for projection of a grating pattern on the disk rather than the single track of the current process. By providing reflection over an area several tracks wide, Iomega says the holographic approach improves the signal-to-noise ratio, which may lead to even tighter control and, hence, a higher track density.

NEW CAPABILITIES. The interweaving of needs and technologies between various user worlds, encouraged in part by the recent multimedia push, continues to usher in new capabilities for both engineering and business users. Often, a technology aimed at one application may ultimately serve a collection of varied needs.

For example, video cards, primarily targeted at multimedia and desktop publishing applications, are now focusing on science and engineering uses. RGB Spectrum suggests that its Watchdog 150/250 could be used for robotics and process control. The Watchdog accepts 15 video inputs of just about any standard type, and can optionally handle such nonstandard signals as radar, infrared, and medical images.

At Univision Technologies Inc., Burlington, Mass., the Piranha includes among its uses command control, medical imaging, image analysis, and CAD/CAE/CAM (computer-aided design, engineering, and manufacturing).

Another potentially large development is the "reality" of virtual reality for Sun 2GT Sparcstations. Input device manufacturer Logitech Inc. recently joined up with StereoGraphics Inc., a maker of stereo viewing systems, on a virtual reality product combination called CrystalEyes VR. Logitech's part of the package is a three-dimensional Mouse and Head Tracker that lets users work in a spatial "virtual environment" to input data into a PC or workstation.

Another technology that has received a lot of attention in larger systems is parallel processing. It comes to PCs and workstations through products that are based on the power-packed Texas Instruments TMS320C40 chip.

Using one or (optionally) two of these chips is Loughborough Sound Images Ltd. in its DPC/C40 AT-compatible plug-in board. Ariel Corp. puts a TMS320C40 on its Cyclops DSP card for 286- through 486-based AT systems. Ariel's Hydra card uses four of the chips, which gives it a capacity of up to 200 Mflops. Hydra plugs into a VME slot and includes a device driver for Sun-3 and Sun-4 workstations.

Elsewhere, 200 Mflops is also the magic number for Alacron Inc.'s FT200 series of multiprocessors, which are based on a choice of one or two Intel i860XP processors. In January, Alacron announced a version that fits into a single 6U VME slot. Possible applications include image processing, 3-D graphics, and neural networks.

WHAT'S IN A NAME? New technologies are popping up so fast in the peripheral industry that some products defy description. For example, what should a card and cable device be called that lets a secondary PC serve as a storage device for a primary PC? Infinicon calls it InfiniStor, identifying it as a personal PC storage expansion system. Reflecting the efficient, resourceful pioneer spirit, InfiniStor aims at turning unused or obsolete PCs into productive devices.

Other developments to watch for are portables used for workstation functions along with docking technology and PC cards. Two products that address the needs of powerful portables are the FileSafe Sidecar 305-MB tape backup subsystem from Mountain Network Solutions Inc., and IOtech Inc.'s DaqBook/100, a data-acquisition add-on that allows notebook computers to perform portable test applications.

PC card readers are another new peripherals area. The Databook PC card reader/writer from Databook Inc., Ithaca, N.Y., plugs into a PC's printer port, enabling users to transfer data between palmtop and desktop PCs through memory cards. The products are making quite an impact as data acquisition and storage devices [*IEEE Spectrum*, June 1992, pp. 46–50].

VICTIMS OF SUCCESS? System makers are including more peripheral-type functions on motherboards, according to market researcher Bennett. This development may cast some peripheral makers in the role of victims of their own success. "Peripheral suppliers are in a very risky and exposed business," Bennett said. "If a function is too successful, the workstation maker will put it on the motherboard, eliminating the third-party peripheral maker." Bennett encourages peripheral makers to enter third-party agreements with system makers to avoid being left out in the cold.

Combine this factor with all the crossover of target markets and new technologies, and life is anything but simple in the peripherals industry. Indeed, as market researcher Bennett commented: "These are interesting times for peripheral vendors." For peripheral shoppers, the times are perhaps even more interesting. ◆

To probe further

For a complimentary copy of the *Executive Summary and Report on* Spectrum's 1993 *Personal Computer Usage and Purchase Survey,* contact Arthur C. Nigro, Marketing Director, *IEEE Spectrum,* 345 E 47th St., New York, N.Y., 10017; 212-705-7298; fax, 212-705-7453.

CONFERENCES. The International Solid-State Circuits Conference (ISSCC), which is held in late winter/early spring each year, is the showcase for the latest workstation chips and the technologies behind them. The proceedings of the 40th ISSCC, held in February at the San Francisco Hilton Hotel (IEEE Cat. No. 93CH3272-2), are available from the IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-981-0060.

During June 14–18 in Dallas, Texas, the 30th Association for Computing Machinery and IEEE Design Automation Conference will feature important electronic design tools for workstations and peripherals. Contact: the Association for Computing Machinery, Order Department, Box 64145, Baltimore, Md. 21264, 800-342-6626.

PUBLISHED WORKS. *Computation Structures* by Stephen A. Ward and Robert H. Halstead Jr. (MIT Press, Cambridge, Mass., and McGraw-Hill Book Co., New York, 1990) deals globally with all the major forms of computer architectures, including reduced-instruction-set computer (RISC) and parallel processing designs. Particular attention is given to logic elements, processors, compilers, operating systems, and, most important, the complex interactions among them.

Various books provide more details on particular processor architectures. The *Alpha Architecture Reference Manual,* edited by Alpha co-architect Richard L. Sites (Digital Press, Burlington, Mass., 1992), explains the technical details of Digital Equipment Corp.'s approach to RISC. On the other hand, *MIPS RISC Architecture,* by Gerry Kane and Joe Heinrich (Prentice Hall, Englewood Cliffs, N.J., 1992), gives a detailed description of the RISC architecture used by Silicon Graphics Inc. in its workstations. Prentice Hall also publishes a Sparc guide and other processor-specific books.

The National Computer Graphics Association (NCGA) publishes information on performance benchmarks in its *SPEC Newsletter,* available at a yearly subscription rate of US $550. It also publishes the *GPC Quarterly Report,* which presents the Graphics Performance Characterization (GPC) committee's benchmarkings of the latest workstations. The report costs $195 annually, $225 outside the United States. Contact: Dianne Dean, the National Computer Graphics Association, 2722 Merrilee Dr., Suite 200, Fairfax, Va. 22031; 703-698-9600; fax, 703-560-2752.

Reliability data (mean time between failures, and more) on leading workstation and peripheral brands are available from Reliability Ratings Inc., Needham, Mass., at an annual subscription rate of US $405. Contact: Reliability Ratings, 175 Highland Ave., Needham, Mass. 02194; 800-477-RELY (United States only) or 617-444-5755; fax, 617-444-8958.

Outside the X Consortium itself, O'Reilly & Associates Inc. is the best source of detailed information on the X Window System. Each quarter, it publishes *The X Resource,* which discusses recent and upcoming additions to the X11 standard, as well as its practical applications. For subscription information, contact: the X Resource, O'Reilly & Associates Inc., 103 Morris St., Sebastopol, Calif. 95472; 800-998-9938 (United States and Canada), 707-829-0515 (overseas or local); fax, 707-829-0104.

Those interested in 3-D graphics and X terminals should look into the *PHIGS Programming Manual* by Tom Gaskins and the *PHIGS Reference Manual* edited by Linda Kosko (both published by O'Reilly & Associates Inc. in 1992).

New developments in graphic technology are reported bimonthly in *IEEE Computer Graphics and Applications.* Contact Nancy Hays, IEEE Computer Society, 10662 Los Vaqueros Circle, Box 3014, Los Alamitos Calif. 90720-1264; 714-821-8380.

In "Revolution or evolution?" [*IEEE Spectrum,* September 1992, pp. 39–41], George Cybenko and David J. Kuck provide an insightful perspective on the future role of supercomputers as shared resources.

Acknowledgments

In preparing this special report, *IEEE Spectrum* called on many experts. We are especially indebted to the individuals listed below for their advice and guidance, although their identification with the report should not be construed as their endorsement of any opinions or products covered in these pages, nor of the accuracy of the statements made in the articles.

The advisers for this report were: Ronald P. Bianchini Jr., assistant professor, department of electrical and computer engineering, Carnegie Mellon University, Pittsburgh; Grant Martin, manager, VLSI design systems, Bell-Northern Research, Ottawa, Ont., Canada; Reddy Penumalli, CAD manager, Analog Devices Inc., Wilmington, Mass.; and David A. Patterson, professor, computer science division, University of California, Berkeley.

Index

Listed below are companies whose products are tabulated in this report; a list of advertisers follows. Page numbers in the editorial index refer to the beginning of the tables in which the products appear. In the advertisers' index they refer to the locations of advertisements. To obtain more information from a company, circle its associated number on the reader service card facing p. 52.

EDITORIAL

OPTICAL DRIVES

Cygnet Systems Inc., 2560 Junction Ave., San Jose, CA 95134-1902, 408-954-1800 **circle no. 306**
Fujitsu Computer Products of America, 2904 Orchard Park Way, San Jose, CA 95134, 800-626-4686 **circle no. 307**
Laser Magnetic Storage International Co., 4425 Arrows West Dr., Colorado Springs, CO 80907, 800-777-LMSI **circle no. 308**
Literal Corp., 2180 Executive Circle, Colorado Springs, CO 80919, 719-579-0460 **circle no. 309**
Pinnacle Micro Inc., 19 Technology, Irvine, CA 92718, 800-553-7070 **circle no. 310**
Plasmon Data Systems Inc., 1654 Centre Pointe Dr., Milpitas, CA 95035, 408-956-9400 **circle no. 311**
Sony Computer Peripheral Products Co., Write Once Optical Products Div., One Sony Dr., Park Ridge, NJ 07656, 201-930-6025 **circle no. 312**

MAGNETIC-TAPE SYSTEMS

Falcon Systems Inc., 1417 W. North Market Blvd., Sacramento, CA 95834, 800-326-1002 **circle no. 313**
GigaTrend Inc., 2234 Rutherford Rd., Carlsbad, CA 92008, 800-743-4442 **circle no. 314**
Sony Corp. of America, 655 River Oaks Pkwy., San Jose, CA 95134-1997, 800-352-7669 **circle no. 315**
Spectra Logic, 1700 N. 55th St., Boulder, CO 80301, 800-833-1132 **circle no. 316**
Tallgrass Technologies Corp., 11100 W. 82nd St., Lenexa, KS 66214, 800-TAL-GRAS **circle no. 317**
Tecmar Inc., 6225 Cochran Rd., Solon, OH 44139-3377, 800-624-8560 **circle no. 318**
Wangtek Inc., 41 Moreland Rd., Simi Valley, CA 93065, 800-882-9916 **circle no. 319**

INPUT DEVICES

DIGITIZER TABLETS

GTCO Corp., 7125 Riverwood Dr., Columbia, MD 21046, 410-381-6688 **circle no. 320**
Hitachi America Ltd., 250 E. Caribbean Dr., Sunnyvale, CA 94089, 408-747-0777 **circle no. 321**
Kurta Corp., 3007 E. Chambers St., Phoenix, AZ 85040, 602-276-5533 **circle no. 322**
Kye International Corp., 2605 E. Cedar St., Ontario, CA 91761-8511, 909-923-3510 **circle no. 323**
Numonics Corp., 101 Commerce Dr., Box 1005, Montgomeryville, PA 18936, 215-362-2766 **circle no. 324**
Science Accessories Corp., 200 Watson Blvd., Box 587, Stratford, CT 06497, 203-386-9978 **circle no. 325**
Wacom Technology Corp., 501 SE Columbia Shores Blvd., #300, Vancouver, WA 98661, 800-922-6613 **circle no. 326**

LIGHT PENS

FTG Data Systems, 8381 Katella Ave., Box 615, Stanton, CA 90680, 714-995-3900 **circle no. 327**

TRACK BALLS

Logitech Inc., 6505 Kaiser Dr., Fremont, CA 94555, 800-231-7717 **circle no. 328**
Micro Speed Inc., 5005 Brandin Court, Fremont, CA 94538, 800-232-7888 **circle no. 329**
Stereo Graphics Corp., 2171 E. Francisco Blvd., San Rafael, CA 94901, 415-459-4500 **circle no. 330**

OUTPUT AND DISPLAY

GRAPHICS ADAPTERS

ATI Technologies Inc., 3761 Victoria Park Ave., Scarborough, Ont., Canada MIW 352, 416-756-0711 **circle no. 331**
Edge Technology Inc., 915 E. Karcher Rd., Nampa, ID 83687, 208-465-3434 **circle no. 332**
Evans & Sutherland Computer Corp., Design Systems Div., 580 Arapeen Dr., Salt Lake City, UT 84158, 800-367-7460 **circle no. 333**
RGB Spectrum, 950 Marina Village Pkwy., Alameda, CA 94501, 510-848-0180 **circle no. 334**
Univision Technologies, 3 Burlington Woods, Burlington, MA 01803, 617-221-6700 **circle no. 335**

HIGH-RESOLUTION MONITORS

Amdek, 3471 N. First St., San Jose, CA 95134-1803, 800-72-AMDEK **circle no. 336**
Sony Peripheral Products Co., Sony Corp. of America, 655 River Oaks Parkway, San Jose, CA 95134-1997, 800-352-7669 **circle no. 337**
Wyse Technology Inc., 3471 N. First St., San Jose, CA 95134-1803, 800-GET-WYSE **circle no. 338**

OTHER DISPLAYS

RGB Spectrum, 950 Marina Village Pkwy., Alameda, CA 94501 **circle no. 339**

GRAPHICS PRINTERS AND PEN PLOTTERS

CalComp Inc., 2411 W. La Palma Ave., Anaheim, CA 92801, 714-821-2000 **circle no. 340**
Fujitsu Computer Products of America, 2904 Orchard Park Way, San Jose, CA 95134, 800-626-4686 **circle no. 341**
QMS Inc., One Magnum Pass, Mobile, AL 36618, 800-631-2692 **circle no. 342**
Tektronix Inc., 26600 SW Pkwy., Wilsonville, OR 97070-1000, 800- 835-6100 **circle no. 343**

COMMUNICATION AND CONTROLS

I/O BOARDS

Analyx Systems Inc., 475 Yampa Way, Fremont, CA 94539, 510-656-8017 **circle no. 344**
IOtech Inc., 25971 Cannon Rd., Cleveland, OH 44141, 216-439-4091 **circle no. 345**
Loughborough Sound Images Ltd., The Technology Centre, Epinal Way, Loughborough, Leicestershire, LE11 OQE England, 011 44 509 231 843 **circle no. 346**
National Instruments Corp., 5404 Bridge Point Pkwy., Austin, TX 78730-5039, 512-794-0100 **circle no. 347**

INTERFACE BOARDS

Barr Systems Inc., 4131 NW 28 Lane, Gainesville, FL 32606, 800-227-7797 **circle no. 348**
Helios Systems, 1996 Lundy Ave., San Jose, CA 95131, 408-432-0292 **circle no. 349**
IOtech, 25971 Cannon Rd., Cleveland, OH 44141, 216-439-4091 **circle no. 350**
Intinicon, 106 Library Pl., 15 N. 100 East, Provo, UT 84606, 800-374-3880 **circle no. 351**
Keithley Data Acquisition, 440 Myles Standish Blvd., Taunton, MA 02780, 800-348-0033 **circle no. 352**
Loughborough Sound Images Ltd., The Technology Centre, Epinal Way, Loughborough, Leicestershire, LE11 OQE England, 011 44 509 231 843 **circle no. 353**
National Instruments Corp., 6504 Bridge Point Pkwy., Austin, TX 78730-5039, 512-794-0100 **circle no. 354**

LOCAL-AREA NETWORK (LAN) BOARDS

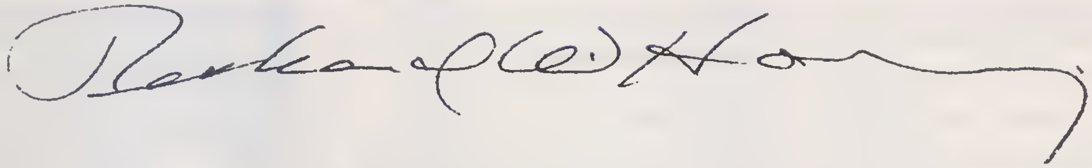
Ansel Communications, 1701 Junction Ct., San Jose, CA 95112, 408-452-5041 **circle no. 355**
Interphase Corp., 13800 Senlac, Dallas, TX 75234, 214-919-9000 **circle no. 356**
Milan Technology Corp., 894 Ross Dr., # 105, Sunnyvale, CA 94089, 408-752-2770 **circle no. 357**

MISCELLANEOUS

ATI Technologies Inc., 3761 Victoria Park Ave., Scarborough, Ont., Canada MIW 352, 416-756-0711 **circle no. 358**
Datacube Inc., 300 Rosewood Dr., Danvers, MA 01923, 508-777-4200 **circle no. 359**
Falcon Systems Inc., 1417 W. North Market Blvd., Sacramento, CA 95834, 800-326-1002 **circle no. 360**
Pinnacle Micro Inc., 19 Technology, Irvine, CA 92718, 800-553-7070 **circle no. 361**
Sony Corp. of America, Image Sensing Div., 10833 Valley View St., Cypress, CA 90630, 714-229-4292 **circle no. 362**
Ultraview Corp., 475 Yampa Way, Fremont, CA 94539, 510-657-9501 **circle no. 363**

ADVERTISERS

Computer Associates, 1 Computer Associates Plaza, Islandia, NY 11788, 800-CALL CAI **circle no. 212**
CSPI, 40 Linnell Circle, Billerica, MA 01821, 800-325-3110 **circle no. 211**
HP Apollo, 19301 Pruneridge Ave., M.S. 46, Cupertino, CA 95014, 800-637-7740, Ext. 7207 **circle no. 210**
Integrated Engineering Software, 46-1313 Border Place, Winnipeg, MAN R3H 0X4, 204-632-5636 **circle no. 207**
Microway, Box 79, Kingston, MA 02364, 508-746-7341 **circle no. 205**
National Instruments Corp., 6504 Bridge Point Pkwy., Austin, TX 78730, 800-433-3488 **circle no. 202**
Numerical Algorithms Group, 1400 Opus Place, Suite 200, Downers Grove, IL 60515, 708-971-2337 **circle no. 204**
Operation Technology, 17870 Sky Park Circle, Suite #102, Irvine, CA 92714, 714-476-8117 or 800-477-ETAP **circle no. 215**
Speakeasy Computing Corp., 224 S. Michigan Ave., Chicago, IL 60604, 312-427-2400 **circle no. 208**
Spectrum Software, 1021 S.Wolfe Rd., Sunnyvale, CA 94086, 408-738-4387 **circle no. 201**
Spyglass, Inc., 1800 Woodfield Dr., Savoy, IL 61874, 217-355-6000 **circle no. 214**
Structural Research & Analysis, 2951 28th St., Suite #1000, Santa Monica, CA 90405, 310-452-2158 **circle no. 209**
TransEra Corp., 3707 N. Canyon Rd., Provo, UT 84604, 801-224-6550 **circle no. 203**
Valley Technologies, RD4, Rte. 309, Tamaqua, PA 18252, 717-668-3737 **circle no. 206**
Wolfram Research Inc., 100 Trade Center Dr., Champaign, IL 61820, 217-398-0700 **circle no. 213**



His invention of error-correcting codes for computers was the result of fortune favoring the prepared mind—and of frustration

Richard W. Hamming was having a bad day. It was 1947, and Hamming was Bell Telephone Laboratories' computer evangelist. He was the one the other Bell Labs researchers would turn to when they found themselves mired in problems they were unable to solve with their then-current hand-driven desk calculators. Hamming would show them how computers could get them going again.

On this Monday, Hamming was expecting a number of useful results from a large-scale relay computer that had been running unattended since Friday evening at Bell Labs' New York City site. But the machine had had a failure early on, and Hamming had no results to give to his colleagues in Murray Hill, N.J.

"Dammit," he thought. "If a machine can find out that there is an error, why can't it locate where it is and change the setting of the relay [from 1 to zero or zero to 1]?"

A mathematician by training, Hamming set out to find an efficient means by which computers could correct themselves. He puzzled over the problem at odd moments, soon finding a solution based on parity checking. Adding extra bits to a block of data would allow not only the detection of bad bits, but their position within the block as well.

He found an even better method several months later, as he was riding in the Bell Labs mail delivery car from New Jersey to New York City.

Hamming concentrated on the problem during the entire ride, since, he said, "New Jersey isn't worth looking at." He thought of more and more efficient arrangements of data, realizing that the real question was, What is the *best* possible solution?

Within a matter of weeks, success was his. His techniques for finding and correcting a single error in a stretch of data, as well as finding two errors and correcting one of them, were to become known as the Hamming Codes. His solution was used by Bell Labs in computer systems and in telephone switching systems.

Tekla S. Perry Senior Editor

Hamming moved on to other projects, and error correction moved on, too, being developed by other scientists into a scientific discipline used in everything from extracting data transmitted from space probes, to recovering jammed communications, to guaranteeing high-quality music from a compact disc.

COMPUTER JANITOR. Hamming's first involvement with the large-scale computing of its day was as the computing maintenance man—a computer janitor, he called it—for the Manhattan Project, whose members built the atomic bomb during World War II.

Becoming interested in mathematics in high school where, during freshman algebra, he realized "I was a better mathematician than the teacher," Hamming had intended to study engineering. But his only scholarship offer came from the University of Chicago, which did not have an engineering school. So he majored in mathematics, going on for a master's degree at the University of Nebraska and a Ph.D. at the University of Illinois, both in mathematics.

'It was science fiction come true, the mad scientist's laboratory'

With those credentials, he expected to have a teaching career, and began one. But that smooth career path shifted after Hamming received a letter from an old friend.

The friend told him: I'm in Los Alamos, and there is something interesting going on down here. Come down and work.

With not much more to go on except that he was needed for war work, Hamming took the train to New Mexico, and his wife followed a month later. They both began work on the Manhattan Project.

Hamming's wife was hired to run a desk calculator, eventually working for Enrico Fermi and Edward Teller. Hamming was taken to a large room where a group of IBM relay computers were clacking away. At night they cast eerie shadows in the dim light. "It was science fiction come true, the mad scientist's laboratory," Hamming recalled, telling *IEEE Spectrum* that his avid interest in science fiction ended that day.

Hamming's job was to keep the computers running so the physicists who had set up the elaborate computations could get back to their work on the atomic bomb. Though Hamming knew nothing about computing on such large machines, he learned quickly.

"And when I had time to think about it, I realized that it meant that science was going to be changed," he said. Experiments were going to be possible with computers that were impossible in the laboratory.

When the Manhattan Project ended after the war, Hamming accepted a job at Bell Telephone Laboratories, but delayed his move to New Jersey. Instead, he stayed in Los Alamos for six more months, even though most of the other scientists had left.

"I wanted to figure out what had happened there, and why it had happened that way," he said. And he wanted to create a written record of what had been computed, because he believed that part of the job of a scientist is to write and teach, to enable others to carry on his work.

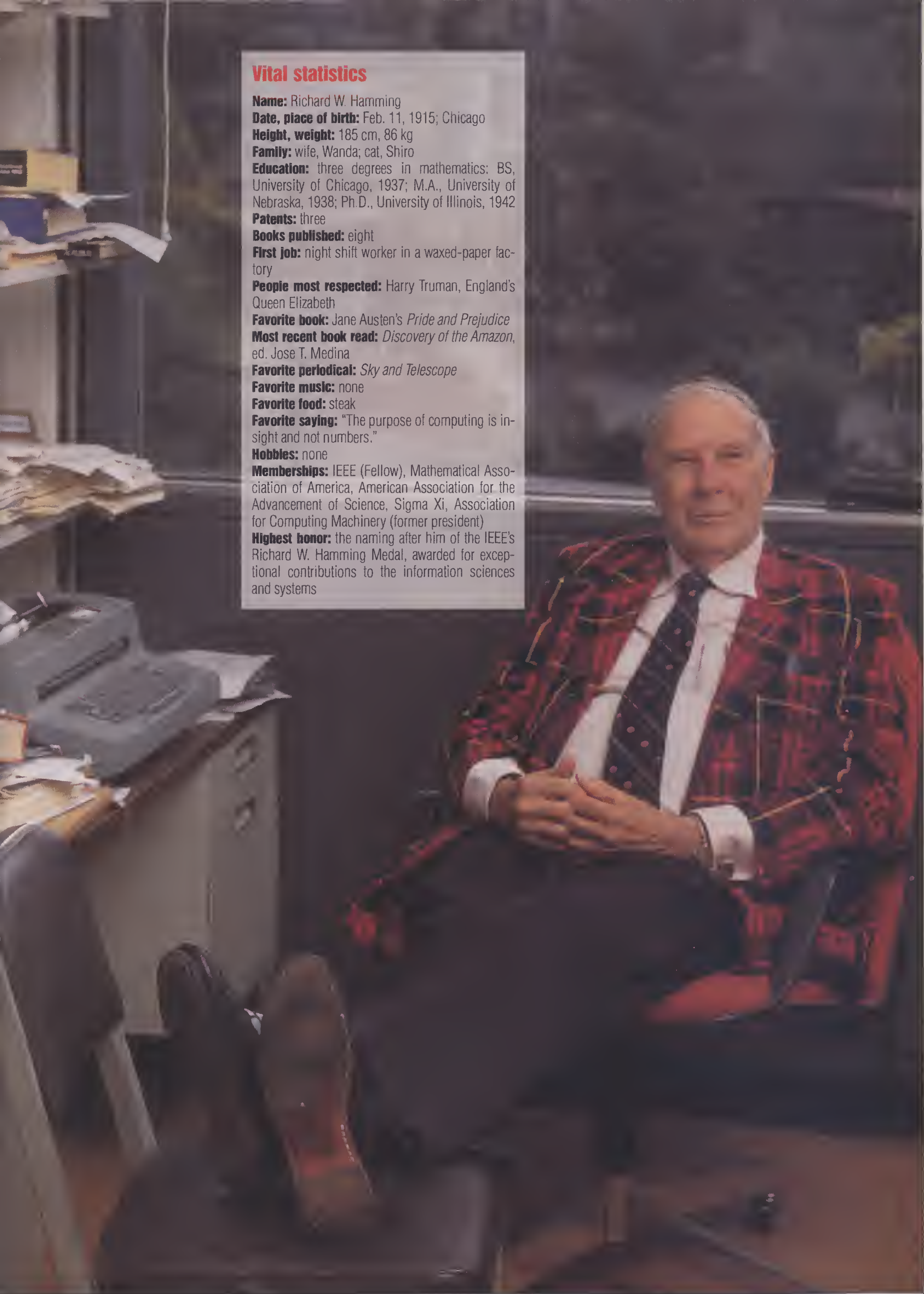
One thing that puzzled him was why the bomb worked so well. Why, when so many of the numbers used in the calculations were of questionable accuracy, were the final computations so accurate? He concluded that it was due to the feedback loops of large-scale computations. Years later this experience served him well as he searched for clues as to why certain failures of early Nike missile test vehicles could also be accurately simulated.

He also asked himself why designing the bomb—an engineering job if he ever saw one—was done by a group of young scientists, not engineers. He concluded that engineering schools do not prepare students to work at the frontier of knowledge. Rather, he said, they prepare them to do run-of-the-mill work, and he thanked his good luck that his original ambition to study engineering had been thwarted. As an engineer," he said, "I would have been the guy going down manholes instead of having the excitement of frontier research work."

YOUNG TURKS. When Hamming finally left Los Alamos for Bell Telephone Labora-

Jon Brenneis

 0018-9235/93/$3.00©1993 IEEE



Vital statistics

Name: Richard W. Hamming
Date, place of birth: Feb. 11, 1915; Chicago
Height, weight: 185 cm, 86 kg
Family: wife, Wanda; cat, Shiro
Education: three degrees in mathematics: BS, University of Chicago, 1937; M.A., University of Nebraska, 1938; Ph.D., University of Illinois, 1942
Patents: three
Books published: eight
First job: night shift worker in a waxed-paper factory
People most respected: Harry Truman, England's Queen Elizabeth
Favorite book: Jane Austen's *Pride and Prejudice*
Most recent book read: *Discovery of the Amazon*, ed. Jose T. Medina
Favorite periodical: *Sky and Telescope*
Favorite music: none
Favorite food: steak
Favorite saying: "The purpose of computing is insight and not numbers."
Hobbies: none
Memberships: IEEE (Fellow), Mathematical Association of America, American Association for the Advancement of Science, Sigma Xi, Association for Computing Machinery (former president)
Highest honor: the naming after him of the IEEE's Richard W. Hamming Medal, awarded for exceptional contributions to the information sciences and systems

tories in 1946, he joined a mathematics department that had recently hired Claude E. Shannon, Donald P. Ling, and Brockway McMillan. The four called themselves the Young Turks. All around 30 years of age, they shared a baptism in scientific research that had started with the war, and they were much alike.

"We grew up in the great depression," Hamming said, "so we believed we owed the world a living. During the war we all had to learn things we didn't want to learn to get the war won, so we were all cross-fertilized. We were impatient with conventions, and had often had responsible jobs very early."

The situation was right for great achievements, Hamming said, and the four went on to fulfill their promise, although not in the way Bell Labs expected. "We were first-class troublemakers," Hamming said. "We did unconventional things in unconventional ways and still got valuable results. Thus management had to tolerate us and let us alone a lot of the time."

Hamming, for one, was hired to work on elasticity theory. But the presence of computers required him to devote more and more time to them, and his career became centered on the computer revolution, with his key advances being made in error-correcting codes and in digital filter theory.

Hamming's contribution to digital filters arose out of his concern for teaching the analog computing specialists the new digital ways of thinking before they became ossified. He was encouraged to write a text for them, learning the field from such digital experts as John W. Tukey and James F. Kaiser.

His work on that text also led to a patent on a new filter design method, and to a certain "window" being named after him. The Hamming window is a statistical tool that lets users look at a small region of a signal, often a spectrum, with the least amount of leakage from any other part of the signal.

These developments illustrated a maxim that Hamming adopted from Louis Pasteur: luck favors the prepared mind. They also fit in with another one of his oft-repeated axioms: "If you don't work on important problems, it's not likely that you'll do important work." The moments of such discoveries are the high points of Hamming's life. He said, "The emotion at the point of technical breakthrough is better than wine, women, and song put together."

But being a first-class troublemaker does not make one universally popular. Some former colleagues from Bell Labs recall Hamming as egotistical, and comment that he occasionally went off "half-cocked, after some half-baked idea," and he was slow to pick up on his misdirection. "He is very hard to work with," one former Bell scientist said, "because he does a lot of broadcasting and not a lot of listening."

Hamming appears to be aware of such feelings. He said, "To reform the system, you have to be willing not to be liked."

MANAGER—NOT. While Hamming believes that he did a lot of good for Bell Labs by bringing in computers, he suspects that he could have contributed more if he had been willing to be a manager. He was not.

Several times Hamming found himself promoted to the head of a department of researchers. As fast as he could, he found those scientists other jobs in the laboratories and transferred them out. "I was so busy doing what I wanted that I couldn't give them the attention they deserved," Hamming said. "I knew in a sense that by avoiding management, I was not doing my duty by the organization" he said. "That is one of my biggest failures."

> 'If you don't work on important problems, it's not likely that you'll do important work'

Frustrated at several points in his career by aging scientists who were taking up space and resources that, he believes, could have been put to better use by young turks like himself, Hamming resolved while still young to retire early and get out of the way. So he ended his career at Bell Telephone Laboratories after 30 years, at age 61.

He still believes his decision was the right one—that mathematicians are most productive early in their careers and their productivity drops off rapidly as they age

That he believes he is right, however, does not seem to make him happy. On an anniversary of Bell Labs, he recalled receiving a commemorative poster listing year-by-year contributions Bell Labs had made to research. Partially unrolling the poster, Hamming scanned the listing for his early years at Bell Labs and noted complacently that he had worked on, or been somehow associated with, most of the chief contributions listed.

He then hung the poster on a door, where it unrolled. Glancing at it again a few days later, Hamming realized that all his valued contributions came in the first 15 years of his tenure—he had not been associated with any of the subsequent projects listed. He tore up the poster and threw it away.

THE PROFESSOR. Hamming knew that the day he left Bell Labs, his research career would be over. But he thought he had another career or two left in him—those of an author and a teacher. He had already written a number of books on computing theory and went on to produce more, continuing his writing even up to this day. His teaching included various evening classes while at Bell Labs, and he decided to expand that experience into a full-time teaching career at the Naval Postgraduate School in Monterey, Calif., because, he said, he wanted to live in California (to escape harsh New Jersey winters) and his wife suggested Monterey.

Life after research has mixed appeal for Hamming, now 78 years old. He finds the students at the Naval Postgraduate School, where he is an adjunct professor, to be "marvelous." "There is no school I know of in which the students are better selected and more likely to be worth the trouble," he said. And he likes the idea that he is teaching people who in 30 years or so will be very important in the military organizations of this and other nations. But he misses the intellectual climate of Bell Laboratories.

Hamming's philosophy of teaching is simple. Since he is preparing students for the year 2020, and he has no clue as to what technology they will be dealing with at that date, whatever subject he is teaching is really a class on learning to learn.

In a basic undergraduate-level circuit theory class, Hamming, who never studied circuit theory, goes through the text with the students, line by line. "I tell them that I will do very little writing on the blackboard. We will learn to read this book, and learn how you go about following a bok full of formulas."

During the class attended by *Spectrum*, Hamming reminded the students that "this is not an exciting class, it is routine and boring. And much of engineering is like that. But I'm teaching you how to learn."

Hamming occasionally digresses to a story about his days at Los Alamos or Bell Labs. The students find the digressions interesting. As for reading the book page by page, well, some say there are more effective ways for them to be taught, particularly in an undergraduate class. "You want the fundamentals drilled into you," one student told *Spectrum*, "so you can do them in your sleep. This is more like a self-taught course."

Hamming still spends a lot of time reading journals to stay technically current on a range of scientific topics. But, he said, annoyed: "I don't keep up as well as I used to. I'm falling slowly behind. There is no way out of it. Frustrating? It's worse than frustrating!"

Hamming expects to retire from teaching in the next three years. With few outside interests, he does not know what he'll do with himself. "A friend told me recently," he recounted, "'Hamming, the day you quit teaching, you are going to fall apart.' He's probably right. When I left Bell Labs, I knew that that was the end of my scientific career. When I retire from here, in another sense, it's really the end." ◆

PRODUCT PROFILES

The PRODUCT PROFILES advertising section provides a distinctive focus on both new and commercially established products and services that offer practical solutions for engineering and scientific professionals in today's fast-paced, rapidly changing high-tech environment.

For rates and production information, phone 212-705-7579

Employment opportunities

Organizations seeking engineers and scientists describe their various openings in the following advertising section In order to conform to the Age Discrimination in Employment Act and to discourage age discrimination, IEEE may reject any advertisement containing any of these phrases or similar ones, "recent college grads," "1–4 years maximum experience," "up to 5 years experience," or "10 years maximum experience." IEEE reserves the right to append to any advertisement, without specific notice to the advertiser, "Experience ranges are suggested minimum requirements, not maximums." IEEE assumes that, since advertisers have been notified of this policy in advance, they agree that any experience requirements, whether stated as ranges or otherwise, will be construed by the reader as minium requirements only. While IEEE does not ban the use of the term "entry level," its use is discouraged since, to some, it connotes an age rather than an experience designation. IEEE accepts employment advertising to apprise its members of opportunities. Interested parties should be aware that the political and humanistic values of certain advertisers may differ from their own. IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

To place an advertisement in *Spectrum*'s Employment Opportunities section, contact the nearest *Spectrum* sales office

New York	Boston	Chicago	San Francisco	Los Angeles	Atlanta	Dallas	Denver
212-705-7760	508-255-4014	708-446-1444	415-386-5202	310-649-3800	404-256-3800	214-553-9896	303-670-3749

For production/mechanical information contact Theresa Fitzpatrick Advertising Production Manager, 212-705-7579

IEEE Spectrum Advertising Dept., 345 E. 47th St., New York, N.Y. 10017

GPS RECEIVERS
TELECOMMUNICATIONS
REMOTE OCEAN SENSING
EHF COMMUNICATIONS
SPACE SYSTEMS
C⁴I

TOMORROW'S TECHNOLOGY TODAY!

If this sounds like the technology you are interested in pursuing, talk to E-Systems, ECI Division. We are in search of talented engineers to staff a variety of existing programs and to lead in the pursuit of new business.

Opportunities exist for individuals with a background in one of the following areas:

GPS RECEIVERS . . . Kalman Filters, Dynamic Simulation, Differential GPS, GPS Inertial Aiding, Attitude Determination.

CRYPTOS . . . Embedded Cryptographic Design, Red/Black Isolation, Security Fault Analysis, NSA Documentation.

TELECOMMUNICATIONS . . . Operational Concepts, ISDN Trunk Interfacing, Acoustic Design, Smart Card Development, Multi-Chip Module (MCM) Technology.

C⁴I APPLICATIONS . . . LANs/WANs, Multi-level Security, RF Modem Design, HF/UHF/VHF, 1MBPS to 5GBPS, 68000/VME Designs.

EHF SYSTEMS . . . Space and Ground Terminals, MILSTAR LDR/MDR Waveform, Up/Downlink Systems.

RF/MICROWAVE DESIGN . . . MIC Solid State Power Amps, Ku Band.

SOFTWARE DESIGN . . . Ada, C, 1750A, RISC, DSP, Real-time, embedded microprocessor, DOD 2167A, CASE Tools, SW Methodology.

E-Systems offers very competitive salaries and an excellent benefits package which includes an Employee Stock Ownership Plan, 401(k), and medical and dental insurance. Qualified candidates should forward a resume and salary history to: Manager of Staffing, E-Systems, Inc., ECI Division, Post Office Box 12248, St. Petersburg, Florida 33733-2248.

E-SYSTEMS
The science of systems.

U.S. Citizenship Required.
Equal Opportunity Employer, M/F, D, V.

W.M. KECK OBSERVATORY

ADAPTIVE OPTICS ENGINEER

The adaptive optics engineer will be a key member of a small team responsible for interface design, installation and testing of adaptive optics components on the two 10m diameter Keck telescopes. Adaptive optics user facilities will be developed and implemented for tilt correction at long wavelengths (5 to 10μm) and higher order correction in the near infrared (2μm). Preliminary requirements and designs will be generated for higher order/shorter wavelength systems using laser guide stars.

Qualifications

Applicants should have a minimum of five years experience in optics and adaptive optics. A Master of Science level degree in optics, physics or electrical engineering, or equivalent experience, is required. Detailed expertise is desirable in the following areas: adaptive optics theory, adaptive optics system design, atmospheric characterization, wavefront sensing and reconstruction, adaptive optics components optical testing, Unix and C programming, and the development of software simulation and analysis tools. Good written and oral communication skills are required and the ability to work independently and as part of a team. The applicant should be physically capable of occasional work at 14,000 feet elevation and must pass a high altitude physical.

Closing date for accepting applications is May 31, 1993.

Interested candidates may submit a resume with salary history and requirements to: California Association for Research in Astronomy, Attn: Adaptive Optics Engineer, P.O. Box 220, Kamuela, HI 96743. FAX 808-885-4464.

CARA is an Affirmative Action/Equal Opportunity Employer. Women and Minorities are encouraged to apply.

ENGINEERING OPPORTUNITIES

Litton Data Systems has achieved a well-respected position as one of the world's foremost developers and manufacturers of military command, control and communications (C³) systems. We are seeking qualified individuals to work on several Air Defense Programs and Rapid Deployment Systems.

TECHNICAL MANAGER
- Digital and voice communications and fiber optics.
- Technical degree with C³I hardware development experience.

PRINCIPAL INVESTIGATOR/IDENTIFIER (IRAD)
- Experience with: Situational awareness based, multi-source, target ID systems and prototype development.
- Advanced degree required.

SYSTEMS ENGINEERS
- Define & structure SW/HW interface requirements IAW 2167A.
- Background in OOA/OOD, CASE tools and Ada.

SOFTWARE ENGINEERS
- Perform detailed design, code, test and documentation.
- Design; Ada and realtime/C³ systems or C, UNIX, UNIX device drivers and PC BIO
- Test: software test IAW 2167A, Ada, OOA/OOD, UNIX, distributed networks and CASE.

Applicants selected will be subject to a security investigation and must meet eligibility requirements for access to classified information. U.S. citizenship required.

For immediate consideration, please forward your resume, including salary history, to: **Litton Data Systems, Employment, Dept. 438, 29851 Agoura Rd., P.O. Box 6008, Agoura Hills, CA 91376-6008.** Principals only please. EOE M/F/D/V.

Litton
Data Systems

Authoritative Works by the World's Most Highly Recognized Experts in Electronics and Computing Engineering

NEW BOOKS FROM IEEE PRESS

The latest developments in one of today's hottest areas of research from the editor of the newest journal in the field...

FUZZY MODELS FOR PATTERN RECOGNITION
Methods That Search for Structures in Data

edited by James C. Bezdek, University af West Flarida and Sankar K. Pal, Indian Statisticol Institute, Calcutta

IEEE Neural Netwarks Cauncil, spansar

Ca-edited by James Bezdek, editar af the new jaurnal IEEE Transactians an Fuzzy Systems, this book shaws yau everything — fram haw the field has develaped ta where it might lead yau in the future.

Beginning with Latfi Zadeh's ariginal 1965 article an fuzzy sets, the editars take yau chranalagically thraugh categaries an the evalutian af fuzzy algarithms far feature analysis, clustering and classifier design, and image processing and visian. Each categary is divided inta tapics in which the warld's leading researchers an the subject discuss everything fram theary ta the practical applicatian af a pattern recognitian system in a design prablem. In additian, each sectian cantains an intraductian to the tapic, camments an the impartance af the tapics selected, and a bibliagraphy far further reading.

March 1992
ISBN 0-7803-0422-5
Order #PC03178-PWM 552pp
IEEE Member Price: $60.00
List Price: $74.95

Offers you the latest information on well-known models and their applications...

ARTIFICIAL NEURAL NETWORKS
Paradigms, Applications, and Hardware Implementations

edited by Edgar Sanchez-Sinencia, Texas A&M University and Clifford Lau, Dept. af the Navy

IEEE Circuits and Systems Saciety and IEEE Neural Netwarks Cauncil, spansars

A camprehensive callectian af the classic faundatians, the latest hardware implementatian techniques, and engineering applicatians af artificial neural netwarks, this baak gives design engineers and technical managers the practical skills required ta succeed. Offering key editarial cammentaries and tutarials, it pravides yau with a well-raunded presentatian of alternative appraaches ta a variety af tapics, alang with key neural netwark references far self-study.

Available April 1992
ISBN 0-87942-289-0
Order #PC02840-PWM
Apprax. 560pp
IEEE Member Price: $55.00
List Price: $69.95

Helps you decipher the theoretical foundations and mathematical analysis behind neural networks...

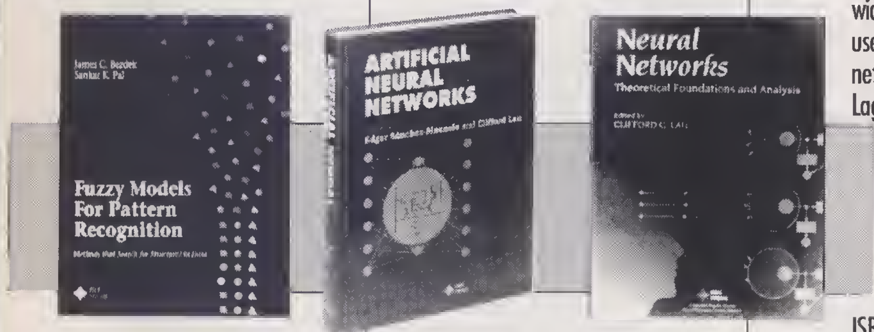
NEURAL NETWORKS
Theoretical Foundations & Analysis

edited by Cliffard Lau, Dept. af the Navy

IEEE Neural Netwarks Cauncil, spansar

Theoretically and mathematically ariented ta build a salid faundatian far future neural research, this baak pravides scientists and engineers with the fundamental mathematical skills needed ta understand bath the capabilities and the limitatians af neural netwark perfarmance. The analytical techniques and thearies presented are widespread and therefare useful ta many specific neural netwark applicatians. Lagically arganized and mathematically rigaraus, it is a valuable reference taal far navices and experi-enced researchers alike.

January 1992
ISBN 0-87942-280-7
Order #PC02790-PWM 336pp
IEEE Member Price: $37.50
List Price: $49.95



The most recent advances and practical applications...

ADVANCES IN ADAPTIVE CONTROL

edited by Kumpati S. Narendra, Yale University; Ramea Ortega, Universidad Nacianal Autanama de Mexica; and Peter Darata, University af New Mexica

IEEE Cantral Systems Saciety, spansar

Written by thase at the farefrant af adaptive cantral technalagy, this valume pravides snapshats af the current status af adaptive cantral af linear, nanlinear, and stachastic systems as evidenced by recent develapments. If yau're an engineer warking in rabatics, flight cantral, space cantral applicatians, pracess cantral, manufacturing, ar autamabile cantral yau will be interested in the valuable tutarial papers, discussians an recent develapments, and camprehensive caverage this valume affers.

1991
ISBN 0-87942-278-5
Order #PC02725-PWM 424pp
IEEE Member Price $55.00
List Price $69.95

All titles are hardcover and are available now except where noted.

Prices are subject to change without notice.

Address orders and inquiries to:
IEEE Service Center
Customer Service Department
445 Hoes Lane, P.O. Box 1331
Piscataway, NJ 08855-1331
1-800-678-IEEE (4333)

The Institute of Electrical and Electronics Engineers, Inc.

Faults & failures

World Trade Center blast triggers design debates

John F. King

Catastrophic failure of communication and power systems followed the Feb. 26 bombing of the World Trade Center in New York City, in which 6 people were killed. In the aftermath, 35 000 building occupants were stranded without lighting or communications, many for up to 5 hours. In rendering two 110-story skyscrapers completely helpless for that length of time, the blast called attention to the vulnerability of large complexes to terrorists and fueled debate among engineers over improvements to power and safety systems to enhance security.

In the wake of the bombing, recommendations were being made on more effective backup for those systems and where they should be located within the complex, the installation of battery-powered devices was being promoted, and fire-fighting tactics for skyscrapers were being questioned.

Meanwhile, the Port Authority of New York and New Jersey, which owns and manages five of the World Trade Center's seven buildings, was busy clearing away the debris, returning the power and communications systems to working order and adding enhanced safety features.

The location of the blast had a lot to do with why the power and communication systems failed. A rented van carrying the bomb, estimated to weigh some 680 kg, was parked in the public parking area in basement level B-2 of the Twin Towers—just below the World Trade Center's sole operations control center, which housed all fire and emergency control functions. The explosion opened a giant hole, at one point 30 meters wide, running downward from the B-1 level to B-6. Concrete, metal, and glass in the area were reduced to an estimated 2600 metric tons of debris.

All systems—including fire alarm, public address, smoke ventilation, and fire and smoke detection—were knocked out. As smoke from hundreds of burning cars poured through the control center, the center's employees were forced to flee, leaving the five buildings without any centralized fire safety communications—although rescue workers with handheld radios were able to supply advice and information to some people inside the buildings.

According to Robert DiChiara, assistant director of the World Trade Department of the Port Authority, power for the authority's five buildings is supplied by eight 15-kilovolt-class feeders from Con Edison, New York's electric utility. The feeders connect to a substation situated on the B-1 level under the Twin Towers and about 60 meters from the operations control center.

Wide World Photos

Workers make repairs at the site of the blast: the underground parking garage at the World Trade Center in New York City. The explosion reduced a large area of the structure to rubble.

The blast ripped apart a splice box containing refrigeration plant feeder cables and crushed the cables inside. Four of the cables were live and faulted, causing their respective 13.8-kV main feeders to fault also. With one of the eight main feeders out for routine maintenance, the remaining three were able to supply only about half power to the two towers and full power to the other three buildings. With the towers at half power, some stairwells were lit, and just half of the elevators were working.

One hour and 15 minutes after the blast, which occurred at 12:18 p.m., the New York City Fire Department ordered the three remaining feeders shut down to guard against the electrocution of firefighters who were trying to put out car fires in a huge, dark hole amid the floods of water that were gushing from a severed water line.

With all main power shut off, the Trade Center's six emergency 1200-kW diesel-driven generators kicked on. According to Jack Buchsbaum, the Port Authority's chief electrical engineer, this backup power would have easily handled the emergency load of 3.5 MW and would have allowed the fire alarm, stairway lighting, and other emergency communications to operate.

But since their cooling water was gushing out of the severed water line, the backup generators almost instantly went down. With the control center disabled, smoke rapidly climbed into the two towers through the ventilation systems and rose up elevator shafts and stairwells.

Already without fire safety communications, occupants of the five buildings then lost all lighting. Thousands groped without guidance through thick smoke and down pitch-dark stairwells—some from the top floor of the towers. Others were trapped in smoky elevators for hours. Wheelchair-bound people on high floors had to wait until power was restored at about 7:00 p.m. that evening to get down by elevator. Complete evacuation of the towers took about 12 hours.

Credit the painstaking, patient efforts of rescuers, the fire and police departments, and building occupants themselves with the fact that no fatalities resulted from panic

Investigating factors contributing to the loss of power, engineers looked at the tripping of the main circuit breakers by the faulted refrigeration plant feeders. "Ideally, it would have been better if our breakers tripped, not Con Ed's," Buchsbaum told *IEEE Spectrum*. Both Con Ed's and the World Trade Center's main circuit breakers feature instantaneous tripping for a bolted short-circuit fault. He said that the Port Authority is exploring methods for delaying the tripping of the Con Edison feeders until the World Trade Center breakers can react to the fault.

The Port Authority's placement of backup generators at a very low level has also drawn criticism. "We always advise people not to put critical facilities at the lowest level of the building," commented Walter Cooper, a telecommunications engineer for Flack and Kurtz, a New York City consulting firm. He and Shelly Steiner, partner in charge of the electrical department at Flack & Kurtz, pointed out that although flooding did not disable the emergency generators, it must be seriously considered in large cities where water-main breaks or inadvertent activation of sprinklers remain a constant threat. The Port Authority, as part of its over-

all improvements, is still considering moving the generators to a higher floor.

At the time of writing, two main power backup possibilities were being examined: tapping into another power grid from Public Service Electric & Gas (PSE&G), the New Jersey utility, or using an alternate Con Edison network. Meanwhile, until all the backup plans are finalized, two air-cooled backup generators are now installed at street level.

Technical means already exist for tapping into the New Jersey utility, since three PSE&G 27-kV feeders enter the World Trade Center to run the Port Authority's PATH commuter rail service. The bi-state agency would simply have to tap into two of those lines, one in each of the two rail tubes, so that the lines could back up one another.

The fact that it would be a first-ever cross-connection of two separate power grids is what may prevent it from happening. There is concern that Con Ed may be apprehensive about another utility coming into its territory.

As a counterproposal, Con Ed has offered to provide the Port Authority with access to another power network on the same New York grid for backup. This would avoid problems from local blackouts, but would still risk vulnerability to a citywide blackout.

But would not all backup plans except for battery power be useless if fire departments need to shut off all power in order to battle blazes in tall buildings? Steiner criticizes what he said is the "standard way of fighting fire in New York City" in turning off the electricity once firefighters arrive. "I'm not a fireman," he admitted, "but I can't for the life of me understand why it's necessary, in every instance, to turn all power off."

"The most important lesson that can be learned from this," said Steiner, "is that wherever there's a fire extinguisher cabinet, there should probably be a rack of locked rechargeable flashlights and perhaps some cellular communication equipment so that people can get instructions as to what to do when the main system is down."

Steiner also contends that there should be differences in the fire-fighting strategies for a 30-meter-high building as opposed to one 300 meters high, but says the fire department makes no distinction.

Captain Brian W. Dixon, director of public information for the Fire Department of the City of New York, when questioned on these issues by *Spectrum*, offered the following written reply: "We have a procedural manual for fighting fires in high-rise office buildings, which we describe as buildings over 100 feet [30 meters] in height. As to the specific operational questions that you pose in regard to the World Trade Center explosion and fire, we are unable to provide you with the answers at this time due to the ongoing investigation of this event."

Security was another area of scrutiny—how can crucial systems be defended against a bomb? "Most people don't have defense against bombs as a primary design criterion," said Cooper. Added Steiner: "Buildings are designed to be safe for occupants during fire conditions, not to withstand bombs."

According to Port Authority officials, their organization commissioned three studies on the dangers of terrorism—in 1985, 1990, and 1991. Those studies concluded that there was little danger of a terrorist attack on Port Authority facilities, and that the towers could withstand the explosion of a car bomb.

Yet the reports also proposed several precautions against critical destruction from a bomb and ensuring smooth evacuation. Battery-powered lighting in stairwells was one key proposal in the 1985 report. It was rejected, according to newspaper accounts, because of the expense and maintenance involved. Other recommendations included closing the underground garage, redistributing facilities throughout the Trade Center, bringing in a redundant source of power from New Jersey, and moving backup generators to a higher floor.

Perhaps influenced by these reports, the Port Authority has recently been laying the groundwork for extensive operating system renovations to its part of the World Trade Center. DiChiara, who is heading the efforts, admits that the bombing probably accelerated the work. It may also have triggered reconsideration of previously rejected ideas.

After the blast, the Port Authority rapidly installed 1600 battery-powered lights on elevators and stairwell landings. These lights will go on automatically should all main and backup power go down. In addition, phosphorescent signs were added to elevators telling the car number and location of intercoms, and also to stairwells to indicate reentry points. Six new satellite fire communications centers will contain two-way RF radios, bullhorns, and flashlights.

Distributing power and communications facilities could also help protect against effects of a bombing. Engineer Steiner is a big advocate of this approach so that "if one thing goes out, it should take out 10 floors from a building, not 100."

Before the blast, the power distribution system at the World Trade Center had the eight main feeders distributed into two risers in each tower, explained Buchsbaum. Each riser used a four-transformer spot network in substations on various floors. With Tower One split into north and south and Tower Two into east and west, the two risers had four rider feeders each; if two went out, the remaining two could carry the load.

Now, two more feeders are being added. Each of the additions will back up a group of four main feeders, in case one of them is out for maintenance. The new feeders will be contained in a fifth riser.

The current central fan-control system is also being changed. It will be divided into separate power zones. If power goes down in one zone, fans in other zones will still operate—and control from more than one location will be possible when a remote control system is in place.

Decentralization of communication facilities could be planned relatively easily, Cooper believes. He claims that statistics show that about 90 percent of telecommunications problems are caused by power problems, not by failures of communications equipment or media.

To avoid the 10 percent of failures not due to loss of power, Cooper favors route, media, and vendor diversity for communications channels and equipment. In case of power failures, he advises a local backup such as a portable uninterruptible power supply (UPS) or a UPS riser. The riser, said Cooper, would follow the telecommunication closets up the building and be provided selectively for such devices as local-area-network concentrators, file servers, multiplexers, and optical-fiber terminals.

As an immediate measure, the Port Authority has decentralized its fire communications operations. Linked to the repaired operations control center are fire communications centers in each of the towers' lobbies and skylobbies. Fire command centers will also be placed in two other areas around the towers and in Buildings 4 and 5. These centers, which combine the advantages of distribution, redundancy, and portability, can be supplied by main and backup, as well as generator and battery power.

In final design before the tragedy and now under construction is a facility that will feature remote control of elevators, fans, TV cameras, and other mechanical and electrical equipment. The agency may also add a completely redundant control center in a remote location.

With engineers working around the clock for a month after the bombing, the Port Authority was able to restore all critical power and communication systems to both towers before April. The battery-powered lights, phosphorescent signs, and fire communications centers were also installed.

Because fires were put out quickly, most equipment throughout the building was left in good shape, and engineers could concentrate on central systems and enhancements. The organization's speed at fixing things won praise from local engineers like Steiner, who said the agency did "a fantastic job of putting systems back together."

Contributing Editor John F. King writes technical articles, computer documentation, and training materials on his PC in Aberdeen, N.J.

COORDINATOR: Linda Geppert

EEs' tools & toys

No-sweat measurement of interconnect parameters

As semiconductor devices go on going up in speed, their packaging and interconnections impinge harder on signal fidelity. Pins, traces, and bonding wires, which once could be treated as zero-impedance nodes, must be modeled as the inductors, capacitors, and delay lines that they really are. The hard part, of course, is then measuring device performance and relating it back to the model.

Taking much of the toil out of that job, the Tektronix IPA 310 Interconnect Parameter Analyzer uses time-domain reflectometry to capture a signature from the device under test, and then processes that information to display impedance information directly. The analyzer's software not only converts reflection coefficients into impedances, but it also corrects for the effects of multiple reflections, thus providing a true impedance value for each of the sections of the distributed interconnect.

Closing the gap between measurement and simulation, the IPA 310 can display the waveform predicted by a Spice simulation (generated by the on-board PSpice program) along with the measured waveform, making it easy to adjust the model to fit reality.

The IPA 310 is priced at US $74 950. The system is based on a 11801A digital sampling oscilloscope, and also includes an 80486-based computer, fixturing, and software. *Contact: Tektronix Inc., Test and Measurement Group, Box 1520, Pittsfield, Mass. 01202; 800-426-2200; fax, 503-690-3959; or* **circle 100.**

Tektronix Inc.

The IPA 310 Interconnect Parameter Analyzer uses time-domain reflectometry to help engineers develop Spice models of packaging and interconnections from measured data.

SOLID STATE

Chips for wireless communications

What with cellular radio, wireless local-area networks, cordless telephones, personal communications devices, and the like, interest in wireless communications devices—especially if they are compact—is running very high indeed. Engineers with a need for information on integrated circuits for such applications will doubtless be interested in a new data handbook put together by Philips Semiconductors.

The 963-page tome includes specifications, packaging, and ordering information on more than 150 ICs and chip sets, including amplifiers, compandors, FM I-F system chips, mixer/front ends, and frequency syn-

EEs' tools & toys

thesizers. Also described is the Philips cellular chip set—12 circuits that can be used to build a complete cellular radio.

The Philips Semiconductors RF/Wireless Communications Data Handbook is available free of charge. *Contact: in Europe, Jan-Willem Reiynaerts, Philips Semiconductors, Corporate Center, Building BAE4, 5600 MD, Eindhoven, The Netherlands; (31+40) 722 653; fax, (31+40) 723 085. In North America, Philips Semiconductors, Box 3409, Sunnyvale, Calif. 94088-3409; 800-447-1500, ext. 3002; or* **circle 101.**

POWER AND ENERGY

In search of efficiency

A recent survey found that a good many electric utilities are interested in investing in companies with exemplary energy-efficiency products. Those polled were the clients of Barakat & Chamberlin, an international consulting firm that advises utilities and other energy-related companies. The firm has therefore instituted a search for such companies to showcase to its more than 100 utility clients. Areas of interest include demand-side management, generation, transmission, and environmental conservation.

Specifically, what the firm is looking for are business plans from emerging companies with patented or proprietary technologies for energy conservation. In addition to introducing selected companies to its utility clients, it intends to work with them on a consulting basis. *Contact: Nancy Floyd, Principal, Barakat & Chamberlin Inc., 1800 Harrison St., 18th Floor, Oakland, Calif. 94612; 510-893-7800; fax, 510-893-1321; or* **circle 102.**

EDUCATION

Giorgi's gift to metrology

It is a sad fact that few of the engineers and engineering students who enjoy the benefits of Giovanni Giorgi's work in metrology today have ever heard of him. Yet it was he who originated the meter-kilogram-second (MKS) system of measurements, which eliminated the incongruities and complications of the old electrostatic and electromagnetic systems. The system, which Giorgi originally described in 1901, was adopted by the International Electrotechnical Commission in 1935 and subsumed into the present International System of Units (SI) in 1960.

To celebrate Giorgi's feat, and to honor the man, a meeting was held on Sept. 21–22, 1988, at the Politecnico di Torino in Turin, Italy, where leading European and U.S. scientists lectured and commented on the details and significance of Giorgi's work. Now the proceedings of that meeting have been collated and edited by the Politecnico's Professor Claudio Egidi, and have been published as a bound volume by the Politecnico in cooperation with the National Research Council of Italy (with an additional contribution from the Centro Studi e Laboratori Telecommunicazioni in Turin).

The volume is now offered free of charge to IEEE members while the supply lasts. It contains the entire proceedings of the special meeting plus reproductions of many historical documents, including Giorgi's 1901 paper. Most of the contents are in both French and English, with some papers in Italian and English. *Contact: Professor Claudio Egidi, Dipartimento di Elettronica, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Turin, Italy; (39+11) 56 44 000; fax, (39+11) 56 44 099.*

Three-day battery update

What do cellular phones, palmtop computers, and electric cars have in common? They are all limited by their batteries. If the battery is too small, the unit will not run for a decent interval between charges. But batteries are heavy, so making them bigger can change a lightweight portable device into a clunker.

What technologies are available today for changing this picture? And how might the picture change in the near future? These questions will be explored at a three-day course, Battery Technology for Electronic Products, to be given May 24–26 at the University of Wisconsin–Madison.

The discussion will deal with energy densities, life characteristics, and charger requirements as applied to product design. It will also cover research and projections about the future growth of battery technology. The fee for the course is US $795. *Contact: Harold Green, Department of Engineering Professional Development, 432 N. Lake St., Madison, Wis. 53706; toll-free, 800-462-0876; or 608-262-2068; or* **circle 103.**

INSTRUMENTATION

Faithful maintenance

The main problem with preventive maintenance is that it often is not done. Maintenance schedules have a tendency to slip as users either forget that servicing is due or decide to delay it because they are reluctant to give up their equipment for what they consider an unnecessary checkup.

Designers, who know that regular maintenance is no luxury, can fight this human tendency with the Model 755 maintenance monitor—an hour meter with a logic function that can be used to activate an annunciator, sound an alarm, or even lock out an equipment function when maintenance time comes around.

Actually, the 755 has a pair of hour meters. One keeps a lifetime record of equipment use, while the other is resettable, and displays use time since the last servicing or time remaining until servicing is due. The unit also has two light-emitting diodes (LEDs): an amber one that lights when 91 percent of the specified service interval has elapsed; and a red LED that lights at 109 percent. The logic function is triggered with the red LED.

Mounted in a 52-mm-diameter case, the 755 lists for US $85; that price drops to $49.30 in hundreds. Delivery is from stock. *Contact: Curtis Instruments Inc., 200 Kisco Ave., Mount Kisco, N.Y. 10549; 914-666-2971; fax, 914-666-2188; or* **circle 105.**

DATA ACQUISITION

Big book of products

Hundreds of products—both hardware and software—for computer-based data acquisition are contained in the 1993 Data Acquisition & Control Buyers' Guide from Omega

Omega Engineering, Inc.

A variety of plug-in boards, software, PC instrumentation, signal conditioners, and communications equipment are among the items detailed in Omega's 1993 Data Acquisition & Control Buyers' Guide.

Engineering Inc. Among the featured products are plug-in boards, software, counters, timers, PC instrumentation, communications gear, motion controllers, and signal conditioners.

The catalog includes pricing data as well as detailed specifications and information on Omega's free technical training and assistance. An Omegafax code, which appears with each product, allows users to receive detailed specification sheets directly on their fax machines.

There is no charge for the catalog. *Contact: Omega Engineering Inc., Box 4047, Stamford, Conn. 06907-4047; 203-359-1660; toll-free, 800-359-RUSH; fax, 203-359-7700. In Europe, Omega Engineering Ltd., Box 1, Broughton Astley, Leics. LE9 6XR, England; (44+455) 285 520; fax, (44+455) 283 912; or* **circle 104.**

COORDINATOR: Michael J. Riezenman
CONSULTANT: Paul A.T. Wolfgang, Boeing Defense & Space Group

READER GUIDE TO PRODUCTS AND SERVICES

IEEE LAN/MAN STANDARDS UPDATE SERVICE

As networking topologies continue to advance to meet growing global communication demands, standardization of local-area networks/metropolitan-area networks (LAN/MAN) architectures and topologies has grown in the IEEE, the leading LAN/MAN standards developer.

Implementing the most current, approved IEEE LAN/MAN standards is critical. But many times, it's difficult to learn exactly when a new LAN/MAN standard has become available—or more importantly, how to get a copy. In response, the IEEE offers its *LAN/MAN Standards Update Service*. Enroll today, and you'll automatically receive one copy of each new IEEE LAN/MAN standard as soon as it's published—and at a 40 percent discount, invoiced with your shipment.

Enjoy the ease and reliability of receiving the newest LAN/MAN standards as soon as they become available. **Sign up today. Call Renee Owens at 908-562-5432**.

For more information, CIRCLE #81 on the Reader Service Card.

AUTOTESTCON '93
September 20-23, 1993

San Antonio Convention Center, Texas

***Theme:* "Enhancing Mission Effectiveness"**

AUTOTESTCON '93 will address technology and systems engineering management issues for enhancing mission effectiveness.

Topics for technical sessions are:

Technology—Enhancing the Mission

Systems Engineering—Enhancing Effectiveness

Test Technology Applied—The True Effectiveness Test

Management Strategies—Shaping the Future

Sponsored by:

The Institute of Electrical and Electronics Engineers

IEEE Instrumentation and Measurement Society

IEEE Aerospace Electronics Systems Society

IEEE Central Texas Section

PLAN NOW TO ATTEND!

For a complete show and conference program, call, fax, or write today to:

AUTOTESTCON '93 Program Committee
Attention: Walter D. Downing
Southwest Research Institute
P. O. Drawer 28510
San Antonio, Texas 78228-0510

Or CIRCLE #82 on the Reader Service Card.

IEEE DRAFT STANDARDS SERVICE

Standards information is critical to you and your organization in helping you stay on the cutting edge of technology. However, there are times when you may need this information before the published standard is available—for instance, to determine how an emerging technology may affect your product or service.

To meet these information needs, IEEE Standards offers the IEEE Draft Standards Service. This unique service makes mature IEEE drafts available. These are documents that are either approved by the IEEE Standards Board and are awaiting publication or are under development but not yet approved. Most versions of IEEE draft standards are available from the IEEE.

To place your order, call IEEE Customer Service at 800-678-IEEE in the United States and Canada; outside North America, call 908-562-1393. Or fax us at 908-981-9667.

For more information, CIRCLE #83 on the Reader Service Card.

1993 IEEE U.S. MEMBERSHIP SALARY & FRINGE BENEFIT SURVEY

Looking for a new job? See how your company compares for salaries and benefits with other employers in the United States. Based on a sample of the U.S. members of the IEEE, the world's leading technical society, the all-new 1993 IEEE U.S. MEMBERSHIP SALARY & FRINGE BENEFIT SURVEY provides you with the current information you need.

A regression analysis is used to predict salaries by analyzing more than 50 individual variables, including primary areas of technical expertise, industry, and geographic location. You'll also get definitive information on salaries by level of education, job

(Continued on overleaf)

READER SERVICE (CIRCLE NUMBERS)

1 PRODUCT INFORMATION

1	10	19	28	37	46	55	64	73	82	91	100	109	118	127	136	145	154	163	172
2	11	20	29	38	47	56	65	74	83	92	101	110	119	128	137	146	155	164	173
3	12	21	30	39	48	57	66	75	84	93	102	111	120	129	138	147	156	165	174
4	13	22	31	40	49	58	67	76	85	94	103	112	121	130	139	148	157	166	175
5	14	23	32	41	50	59	68	77	86	95	104	113	122	131	140	149	158	167	176
6	15	24	33	42	51	60	69	78	87	96	105	114	123	132	141	150	159	168	177
7	16	25	34	43	52	61	70	79	88	97	106	115	124	133	142	151	160	169	178
8	17	26	35	44	53	62	71	80	89	98	107	116	125	134	143	152	161	170	179
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135	144	153	162	171	180

MEMBERSHIP INFORMATION

300 Regular 301 Student

Print or Type only

Name ______________ Title ______________

Company ______________

Address ______________

City ______________ State ______ Zip ______________

Country ______________ Business Phone ______________

If this represents a change in address, please fill out form on p. 9

3 ADDITIONAL COMMENTS

____

____

I would like: ______________

DELIVERY: I received this issue ______________ (date).

For faster delivery, fax this card to 413-637-4343 **5**

Void after August 1, 1993 *Void overseas September 1, 1993*

READER FEEDBACK (CIRCLE NUMBERS)

2 EDITORIAL MATTER

Article/Item	Comment: Too simple	Just right	Too detailed
Epidemiology of computer viruses	01	02	03
The blue laser	04	05	06
Profile: Richard W. Hamming	07	08	09
Newslog	10	11	12
EEs' tools & toys	13	14	15
Program notes	16	17	18
Faults & failures	19	20	21
Technically speaking	22	23	24
Engineer at large	25	26	27

Did you find this material stimulating or thought-provoking?

Item	Yes	No
Reflections	28	29
Forum	30	31
Books	32	33

The engineer at large

Russian medal goes to NOAA scientist

The Lomonosov Medal, the highest civilian science award the Russian government can bestow on a noncitizen, has been awarded to Joseph O. Fletcher, formerly of the U.S. National Oceanic and Atmospheric Administration (NOAA). As a senior scientist and science administrator there, he played a leading role fostering cooperative U.S.-Russian scientific research, especially in the Arctic, said Academician Nikolay P. Laverov, former USSR vice premier for science and technology and now vice president of the Russian Academy of Sciences.

In a ceremony at NOAA's Environmental Research Laboratories in Boulder, Colo., which Fletcher headed until recently, Laverov stressed the U.S. scientist's "enormous contribution to earth sciences." He pointed out that Fletcher's encouragement of joint cooperative science investigations extended through the Cold War years. As indicative of Fletcher's interest in cooperative research, Laverov noted that more Russian scientists are engaged in more projects at the Boulder laboratories than at any other site outside Russia.

Fletcher, a meteorologist and physicist, retired from government service earlier this year. He is now senior research associate with the Cooperative Institute for Research in Environmental Sciences, jointly sponsored by NOAA and the University of Colorado.

Master materials builder honored

For "originating the field of strained-layer superlattice electronics and optoelectronics" as well as inventing important new electronic and optical devices," physicist Gordon C. Osbourn of Sandia National Laboratories in Albuquerque, N.M., has been chosen to receive the American Physical Society's 1993 International Prize for New Materials. The award honors his theory and Sandia innovations that have already led to a variety of commercial semiconductor devices and that open up "almost infinite chemical combinations for designing new materials having special electrical and optical properties," according to a statement released by Sandia.

Osbourn made the first theoretical calculations that predicted the unique electrical and optical properties of strained-layer superlattice (SLS) materials. This theory and the subsequent development of the technology by him and numerous Sandia colleagues now enable researchers to tailor materials to have desirable optical and electronic properties, such as semiconductor lasers and transistors for high-frequency, low-noise electronic amplifiers.

Attracting women to engineering

Like to encourage women to pursue careers in science and engineering? A recent report from the National Research Council, Washington, D.C., compiles articles on intervention programs that strive to attract women to science and engineering and then help keep them on a career track.

Such programs can help increase the numbers of women in the field, according to the report, "Science and engineering programs: On target for Women?" The report is available for US $19 plus shipping from the National Academy Press; call 202-334-3313 or 1-800-624-6242.

Tuition to young inventors

An accelerometer, a portable rocket-launch pad, and an alarm that reacts to a pot boiling over were some of the battery-powered devices that won six high-school students top honors in the Eleventh Annual Duracell/National Science Teachers Association (NSTA) Scholarship Competition. The winners, along with their parents and science teachers, were guests of Duracell Inc. at an awards ceremony in Kansas City in April.

The first-place scholarship of $10 000 was awarded to Aaran James Passey, of Bothell, Wash., for the accelerometer, which measures and displays acceleration and changes in acceleration in real time. Powered by a 9-V battery, the device contains two analog peak detectors; light-emitting diodes (LEDs) display the output. Passey hopes to study physics next year at the California Institute of Technology in Pasadena.

The five second-place winners each received scholarships worth $3000. James Richard Adams, a sophomore at Elkhorn High School, Elkhorn, Wis., designed and built a briefcase-sized launch base capable of launching up to four model rockets via remote control.

Justin Phillip Chester, of Colorado Springs, Colo., invented the "car-jack jinx," which allows a car's ignition to be turned off while the vehicle is being driven away; the device separates the car's ignition coil from its electrical ground.

Timothy John Hess, a senior at Triad High School in Marine, Ill., invented an electronic precision vise that is operated by pedal rather than handle, thereby allowing a machinist to hold two pieces of metal and tighten the vise at the same time.

Edmund Forrest Loftus of Gainesville, Fla., received his scholarship for Stoveguard, a safety device that sounds an alarm and turns off the cooking surface when a pot of liquid boils over. It consists of two AA batteries, a sensing grid and circuit, and a turn-off module.

Annette Elise Piepenhagen, a senior at Thomas Jefferson High School in Alexandria, Va., invented a learning aid she calls the katakana blackboard. The device shows the user how to draw 46 characters from katakana, the script the Japanese use for words of foreign origin.

Datacom pioneers recognized

Every year, the Electronics Frontier Foundation bestows Pioneer Awards on those who have made influential and noteworthy contributions to the field of computer-based communications. This year's recipients included four IEEE members involved in packet switching, TCP/IP, and Usenet.

Paul Baran (LS), of Atherton, Calif., pioneered the concept of packet switching, which made possible the efficient and simultaneous transmission of many messages from many sources to many destinations over the same circuit.

Vinton Cerf (F), of Reston, Va., was a leader of the research project that developed the TCP/IP protocol suite, the open system interconnection protocol used to communicate over the Internet. He also participated in the development of Arpanet host protocols and led the engineering effort to develop MCI Mail.

Tom Truscott (M), of Triangle Park, N.C., and James Ellis (M), of Burlington, Mass., together developed the software for Usenet, the distributed bulletin board system read by approximately two million people worldwide.

The other Pioneer Award recipients were Ward Christensen, who wrote the original software for what came to be called Xmodem, and Dave Hughes, an outspoken evangelist for computer networking and electronic democracy who brought the municipal elected government of Colorado Springs, Colo., on-line.

The Electronics Frontier Foundation is a nonprofit organization funded by individual and corporate contributions. Headquartered in Washington, D.C., it was founded in 1990 to ensure that the principles embodied in the U.S. Constitution and the Bill of Rights are protected as new communications technologies emerge.

COORDINATOR: Alfred Rosenblatt

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, goverment, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

ADVERTISING RATES

Positions open—$36.00 per line, not agency-commissionable

Positions wanted—$36.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy.

All classified advertising copy must be received by the 25th of the month, two months preceding the date of issue. No telephone orders accepted. For further information call 212-705-7578.

IEEE encourages employers to offer salaries that are competitive, but occasionally a saslary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic positions open

The EEE Dept. of the Hong Kong University of Science and Technology invites applications for tenure-track faculty position at Lecturer, Senior Lecturer, Reader and Professor ranks. The department is in its 2nd year of operation and currently has 250 UG and 50 PG students. The department has 22 full-time faculty and is planning to expand to 32 full-time faculty members this year. Areas of particular interests include IC design, microelectronics, photonics, microsensors, robotics, communications, information and systems, and computer engineering. We are seeking highly qualified Ph.D. applicants with demonstratable experience in teaching and research. Salaries are competitive to the U.S. with generous benefits such as 6 weeks of paid annual leave, two weeks of short leave, housing subsidy and home passages, etc. for qualified candidates. For further information, please contact Professor Peter Cheung, Head, Dept. of Electrical and Electronic Engineering, HKUST, Clear Water Bay, Kowloon, Hong Kong.

Stanford University, Department of Electrical Engineering - Faculty Opening. The Department of Electrical Engineering at Stanford University invites applications for a tenure-track faculty position in the field of high-speed circuits. Applicants should have an earned Ph.D., demonstrated research ability, and a strong interest in graduate and undergraduate teaching. The field of interest is broadly interpreted to mean the design of circuits employing novel and emerging mainstream semiconductor technologies to solve problems in high-speed electronic systems, with an emphasis on broadband communication systems such as those based on wireless and optical fiber transmission. Candidates should have a demonstrated interest and record of accomplishment in the design, fabrication and testing of analog and digital integrated circuits at the transistor level. They should have a good knowledge of semiconductor integrated circuit technology, and it is essential that their research interests include a strong experimental component. They must also be interested in developing and teaching both undergraduate and graduate courses in electronic circuit design, with an emphasis on nonlinear analog circuits and circuits for high-speed communications. The appointment will be at the Assistant or Associate Professor level. Please send a complete resume, a publication list, and the names of at least five references to Professor Bruce Wooley, Search Chairman, Department of Electrical Engineering, CIS-206, Stanford University, Stanford, CA 94305-4070. Applications should be received by July 1, 1993. Stanford University is an equal opportunity/affirmative action employer and especially encourages applications from women and minority candidates.

Chairperson, Electrical Engineering. The Department of Electrical Engineering at The Ohio State University is seeking nominations and applications for the position of Department Chairperson, effective sometime after July 1, 1993. The position is for a tenured appointment at the rank of Professor in the Department of Electrical Engineering. The qualifications desired include a doctorate in electrical engineering or a closely related field; a strong commitment to all aspects of education at both the graduate and undergraduate levels; recognized stature in research, with a distinguished record of scholarly publications; involvement in professional society activities; demonstrated leadership and organizational abilities in either government service, industry, or academia; and a strong interest in enhancing the Department's reputation. The Department consists of 43 faculty members, a research and support staff of 42, and over 700 undergraduate and 270 graduate students. Traditionally, there has been a strong emphasis on both effective teaching and outstanding research. External funding for the latter, which is in excess of $5.5 million annually, involves support in analog and digital VLSI circuits, computer engineering, control, electric power systems, electromagnetics, electro-optics, manufacturing and robotics, signal and image processing, and solid-state microelectronics. Commensurate with this level of research activity, the Department has impressive research and teaching laboratory facilities and extensive local computer resources enhanced by the Ohio Supercomputer Center, located on campus. Interested applicants should submit resumes, which include the names of at least three references, to Professor Umit Ozguner, Chairman, Search Committee, Department of Electrical Engineering, The Ohio State University, 2015 Neil Ave., Columbus, Ohio 43210-1272, (614) 292-5940, csearch@ee.eng.ohio-state.edu. The Ohio State University is an Equal Opportunity/Affirmative Action Employer. Qualified women, minorities, Vietnam-era veterans, disabled veterans, and individuals with disabilities are encouraged to apply.

University of Florida, Faculty Position in Electrical Engineering at the Graduate Engineering and Research Center at Eglin Air Force Base. The Department of Electrical Engineering invites applications for a tenure-track position in the area of electro-optics. The academic rank will depend upon the qualifications of the successful candidate. Possible areas of interest include, but are not limited to: holography, interferometry, optical communications, optical signal processing, optoelectronics and integrated optics. Familiarity with acoustooptic cells, spatial light modulators and especially high speed microwave circuits would be especially useful. Applicants must possess a doctoral degree and show a strong record/commitment to graduate teaching and experimental research in electro-optics. The person selected must be able to qualify for a DOD secret security clearance. The position is available starting in the summer of 1993. Resumes and the names and addresses of four references should be sent to Professor Ramu V. Ramaswamy, Chairman, Faculty Search and Screen Committee, Electrical Engineering Department, 216 Larsen Hall, University of Florida, Gainesvile, FL 32611-2044, phone (904) 392-9265, e-mail: Ramu@eng.ufl.edu. Application deadline is May 31, 1993. The University of Florida is an equal opportunity/affirmative action employee and women and minorities are encouraged to apply. According to Florida law, applications and meetings regarding applications are open to the public upon request.

Princeton University: The Department of Electrical Engineering invites applications for a full time, tenure-track, junior or senior faculty position. The areas of particular interest are Computer Architecture, Parallel Processing, and other closely related disciplines in Computer Engineering. Please send a complete resume, a description of research and teaching interests and names of three references to Professor Stuart Schwartz, Chairman, Dept. of EE, Princeton University, Princeton, NJ 08544. An Affirmative Action/Equal Opportunity Employer.

The Johns Hopkins University School of Engineering seeks a Director for the newly created Center for Speech Processing. The director will hold a tenured professorship in the School of Engineering. The center will add new computing facilities, as well as graduate student and postdoctoral support to existing speech research activities in the University. It will host visiting scholars, workshops, and the annual Speech Research Symposium. The director's responsibilities will include center leadership as well as working closely with governmental and industrial partners to insure success and expansion of the interdisciplinary research and education activities in the center. Candidates should be recognized authorities in an area of speech science and technology. Emphasis will be given to the quality and depth of a candidate's academic expertise and leadership record. Nominations and applications (including CV's, and the names, addresses and telephone numbers of three professional references) should be sent to Center for Speech Processing Search Committee, 105 Barton Hall, G.W.C. Whiting School of Engineering, The Johns Hopkins University, Baltimore, MD 21218. Applications will be accepted until May 15, 1993, or until the position is filled. The Johns Hopkins University is an Equal Opportunity/Affirmative Action Employer.

Electrical Research Engineer - Will design and conduct experiments in holographic recording, optical and digital image reconstruction of submicron aerosol particles, and light scattering using optical instrumentation for the study of the dynamics of submicron particles in filtration. Requires M.S. in Electrical Engineering with specialization in optics and two years research experience in applied optics and aerosol science. Established research background documented by publications in refereed journals and conferences. Five days, 37.5 hrs./week, $26,000/yr.. Send resume in duplicate to M. Johnson, NYS Department of Labor, 280 Main Street, Buffalo, New York 14202, Job Order #0703954.

Head, Electrical and Computer Engineering. The University of Southwestern Louisiana invites nominations and applications for the position of Head. Screening will begin immediately and will continue until the position is filled. Qualifications include a Ph.D. in Electrical Engineering or equivalent, a demonstrated record in research, teaching, and administrative capability. The position is at the rank of Full Professor. Candidates must be U.S. citizens. The Department of Electrical and Computer Engineering is one of seven departments in the College of Engineering. The Department has 13 faculty and offers the Bachelor of Science degree in Electrical Engineering and is the lead department in the interdisciplinary Master of Science in Telecommunications. The M.S. and Ph.D. in Computer Engineering are offered through the Center for Advanced Computer Studies. One focus of the Department is to extend the M.S. in Telecommunications to the Ph.D. level. The applicant should send a resume and names and telephone numbers for three references to: EECE Department Head Search Committee, USL P.O. Box 43890, Lafayette, LA 70504. USL is an Equal Opportunity Employer.

The CAD Center in the Department of Electrical and Computer Engineering at Carnegie Mellon University seeks candidates for the position of Assistant Director. The CAD Center is home to roughly ten ECE faculty and fifty ECE graduate students working together to design the next generation of electronic design automation (EDA) software for the synthesis, verification, and manufacture of complex integrated circuits and systems. Research in the Center is funded from a variety of sources, including the Semiconductor Research Corporation, Sematech, the National Science Foundation, and numerous

individual industrial sponsors. Responsibilities include: monitoring the day to day operations of the Center; managing the condition and evolution of our workstation/network infrastructure; tracking sponsored research contracts; marketing graduating students and Center-generated intellectual property to industry; serving as technical liaison between the Center and our industrial sponsors, with particular emphasis on devising and managing strategies for rapid technology transfer to industry. Candidates should possess at least an M.S. in Electrical or Computer Engineering. Industry experience in at least one of the following areas is required: EDA software tool design or integration, integrated circuit design, test, packaging or manufacture. Candidates must also show evidence of success in managing the interactions between a technical R&D organization (commercial or university) and industrial sponsors and end-users of the new technology produced. Carnegie Mellon University is an equal opportunity affirmative action employer and welcomes applications from women and minority groups. Send vita and names of references to Prof. Rob A. Rutenbar, Director, SRC-CMU CAD Center, Dept. of Electrical and Computer Engineering, Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, PA 15213.

California State University, Los Angeles - Department of Electrical and Computer Engineering anticipates an opening for a full time temporary faculty member with experience and expertise in Computer Hardware and Architecture. Apply to Dr. Martin S. Roden, Chair, Electrical and Computer Engineering, California State University, Los Angeles, CA 90032-8152. Deadline for first consideration is May 15, 1993. An Equal Opportunity/Affirmative Action/Handicapped/Title IX Employer.

Head, Electrical and Computer Engineering: The University of Tennessee, Knoxville (UTK) invites applications and nominations; required qualifications include: (1) earned doctorate in electrical engineering, or in a related field with extensive electrical engineering experience; (2) eligibility for rank of Full Professor at UTK; (3) record of excellence in graduate and undergraduate teaching, research, and professional practice in electrical engineering; (4) balanced perspective on teaching and research, vision and commitment to planning, administrative ability, and strong interest in acting as an enabler of people; (5) ability to interact with a wide range of personalities and willingness to participate in all aspects of campus and community life that promote the well-being of the department and the college; (6) willingness to commit time and energy to work with external constituents, including prospective students and their parents, alumni, employers, research sponsors, and potential donors; (7) satisfaction of eligibility requirements for a Department of Energy "Q" clearance and/or Department of Defense "Secret" clearance; and (8) understanding of and demonstrated commitment to equal employment opportunity and affirmative action. Applications and nominations should be sent to the Search Committee chair: Dr. John W. Prados, Chair, ECE Department Head Search, 419 Dougherty Engineering Building, The University of Tennessee, Knoxville, TN 37996-2200. Interested individuals should submit a resume and letter of interest detailing the applicant's specific talents and experience as related to this position, date and conditions of availability, and the full names, addresses, and telephone numbers of five references. Applications are not returnable. Review of applications will begin on or about 1 June 1993 and will continue until the position is filled. UTK is an EEO/AA/Title IX Section 504/ADA Employer.

Institut Eurecom - Assistant Professor - Institut Eurecom a graduate school and research institute in communication systems located in Sophia-Antipolis (south of France) is seeking an applicant for a position at the Assistant Professor level. The candidate will join the Mobile Communication Department. He must hold a Ph.D. degree and have demonstrated potential for teaching and research. Preference will be given to candidates with research experience in the area of digital mobile communication techniques, systems or applications. Institut Eurecom was founded in 1991 by the Swiss Federal Institute of Technology in Lausanne (EPFL) and the Ecole Nationale Superieure des Telecommunications (ENST) in Paris. It has 9 professors with international backgrounds. Lectures are given either in French or English. Please send your curriculum vitae, 3 references and a statement of research interests before the end of June to Antoine Perry, General Manager, Institut Eurecom, CICA, 2229 route des Cretes, Parc de Sophia-Antipolis, 06560 Valbonne, France.

Computer Science and Engineering. Northern Arizona University, Department of Computer Science & Engineering is seeking applications for a tenure track assistant professor beginning Fall 1993. Applicants must have a Ph.D. in Computer Science, Computer Engineering, Electrical Engineering, or associated field. Candidate must have experience in digital design, systems design, networking and embedded microcontrollers. The position will remain open until filled; however, the Screening Committee will begin reviewing applications as they are received. Direct inquiries and applications to Dr. Lanny Mullens, Chair, Department of Computer Science & Engineering, College of Engineering & Technology, Northern Arizona University, Box 15600, Flagstaff, Arizona 86011-1560. Northern Arizona University is a committed Equal Opportunity/Affirmative Action Institution. Minorities, Veterans, Women and Persons with Disabilities are encouraged to apply.

Research Associate/Post-Doctoral Fellow. Division of Pulmonary Medicine seeks qualified applicants for a Post-Doctoral Research Fellow position. Strong background in signal processing/time series analysis and computer skills necessary. Ph.D. required, Biomedical or Electrical Engineering preferred. Ability to work independently and knowledge of respiratory physiology/monitoring helpful. Faculty appointment and salary up to $35,000 plus benefits depending on qualifications and experience. Funding guaranteed for 3 years. Send resume and 3 letters of reference to Frederick J. Curley, M.D., Pulmonary, University of Massachusetts Medical School, 55 Lake Ave. N., Worcester, MA 01655. An Equal Opportunity Employer.

Research Assistant Professor. University of Arizona seeks a Research Assistant Professor (non-tenure-eligible position) qualified to assume major responsibility for all software, hardware, and image reconstruction aspects of a program to develop novel medical imaging (SPECT) systems based on modular scintillation cameras and coded apertures, and to ready the system for clinical trials. Required: Experience with/understanding of scintillation detectors, scintillation cameras, SPECT< UNIX and C. Desirable: Two years of postdoctoral experience including nuclear medicine instrumentation design, VME-based and parallel computers, tomographic/3-D reconstruction, and clinical studies. Special U of A research strengths include medical imaging, optical sciences, and neurosciences. Postdocs will be considered. Salary commensurate with experience. Submit CV and 3 supporting letters to: Dennis D. Patton, MD, Division of Nuclear Medicine, University Medical Center, Tucson, AZ 85724. Tel. 602-626-7709, Fax 602-694-2412. Application deadline: June 1. The University of Arizona is an Equal Opportunity/Affirmative Action Employer.

University of Nevada, Reno-Faculty Position. The Department of Electrical Engineering at the University of Nevada, Reno invites applicants for a 0.5 FTE non-tenure track position beginning with the academic year 1993-1994. The candidate will be expected to provide 0.5 FTE in external research funding. Applicants must have earned a Ph.D., have outstanding academic credentials, strong research interests, and an ability to teach effectively at both the undergraduate and graduate levels. Industrial experience is also desired. The selected candidate will be encouraged to initiate and carry out funded research with existing research groups in the areas of computer, power, or microwave engineering. The department has 9 full-time faculty positions and about 300 students at the B.S., M.S., and Ph.D. levels. All qualified individuals are encouraged to apply. Send resume to: Dr. Dwight Egbert Search Committee Chair, Electrical Engineering Dept./260, University of Nevada, Reno, Nevada 89557-0153. Phone: 702-784-6952, Fax: 702-784-6627. Deadline is June 1, 1993 or until filled. The University of Nevada is an EEO/AA employer.

Government/Industry Positions Open

RF Design Engineer. A consumer electronics company is seeking an individual to head up a development team. Candidate must have a strong RF background in design and layout. Must be familiar with programing GALS, PALS and PROMS. J-Deck file exp., Proficient with logic analyzers, machine language. CAD, math CAD. A background in CATV converter design and development would be a plus. Send resume with two references to: Everquest Inc., Engineering Div., 875 South 72nd St., Omaha, NE 68114.

Electrical Engineer - Design hi-speed CMOS ICs. Req. PhD EE and 6 mos. exp. as electrical engr. or research assistant incl. 400 mhz. designs and knowledge of Mentor, GDT, LSIM and HSPICE. Job Location: Los Angeles, CA. Salary: $70,000/yr. Send this ad and your resume to JOB#TC11972 P.O. Box 269065, Sacramento, CA 95826-9065 no later than May 31, 1993.

Development Engineer for Southwestern Ohio manufacturer/seller of machine tools, plastics processing machinery and industrial products. Duties: Conduct research and development activities related to the engineering, manufacturing, and testing of electromechanical motion devices (drives, controls); application of brushless DC motor drive and control technology to variable speed products, such as plastics processing machines; evaluate the applicability and functionality of brushless DC motor technology; develop applications of brushless DC motor drives and controls to manufactured products; provide electromechanical engineering specifications for various variable speed applications of brushless DC motor drives and controls; establish design standards and tolerances; establish methods, procedures, and conditions for testing brushless DC motor drive and control applications to ensure conformance with functional specifications and customer requirements. Duties are based at a S.W. Ohio facility of employer but also will be regularly performed (on average, about 20% of the workweek) at another S.W. Ohio facility of employer, approximately 30 miles away. Minimum education requirements: Master's in Electrical Engineering. Education must have included at the graduate level a minimum of 6 (semester) credit hours in electromechanical motion devices course work. (Equivalent quarter hours are acceptable.) Minimum experience requirements: One year's experience in the above described job duties, or one year's electrical engineer experience responsible for the design and development of brushless DC motor drive and control technology for variable speed applications. Acceptable in lieu of the required experience is a completed graduate thesis or project concerning the design and development of brushless DC motor drive and control technology for variable speed applications. Basic hours, 42.5 per week, 8 am - 5 pm, Mon. - Fri. $38,805 salary/year. Must have proof of legal authority to work indefinitely in U.S. Qualified applicants send resume in duplicate (no calls) immediately to J. Davies, Job Order No. 1230897, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Electrical Engineer needed for company located in West-Central Ohio. Job duties include research and study of existing antennas; development of new antennas; development of softwares for analysis and design of antennas; and establishment of antenna measurement system. Applicant must have a Ph.D. in Electrical Engineering. Applicant must also have the following: 1 yr research exp in the fields of antenna design, antenna optimization or antenna synthesis to

have been gained before, during or after degree; a minimum of 2 publications in antenna design, antenna optimization, or antenna synthesis; must have a specialized graduate study in the field of antennas evidenced by minimum of 8 of the following courses related to: Microwave Circuits, Electromagnetic Fields, Antenna Radiation, Electromagnetic Radiation Antenna Theory, Microwave Optics, Radar Systems, Space Communications, Digital Signal Processing, Communications Theory, or Communications Systems. Must present proof of legal authority to work permanently in the U.S. 40 hrs per wk, 9:00am to 5:00pm, Mon through Fri $44,039.84 per yr. All resumes should be submitted in duplicate (no calls) to: J. Davies, JO# 1367287, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Engineer, Sr. Member of Technical Staff. Devlp state-of-the-art Analg Integrtd Circuit performance driven automtc placment sftwr. Knwldg of perfrmance driven Analog placment sftwr. Knwldg of & able to use circuit simlation prgrms such as SPICE for sensitivity anlysis & optimzation. Knwldg of CAD framwrk basd develpmnt for CAD tools such as OCT, CFI & DFII. Able to prgrm i/UNIX, C, C++, & either LISP or smalltalk on SUN w/k. Jobsite: San Jose, CA. Ph.D. i/EE, CS or equiv. Entry Levl. $60,000/yr. 40hrs./wk. Clip ad & submit w/resume to: IEEE Spectrum, Box 5-1, 345 E. 47th St., N.Y., N.Y. 10017 no later than May 10, 1993.

Telecom Engineer with Project Management experience, familiar with VSATs, radios, PBXs and microwave, to manage international team of engineers. Preference to diplomatic person with can-do attitude. Please fax resume to Vice President, 212-755-0864.

Engineer, Senior Component Design: Conduct VLSI microprocessor & component design; perform behavioral & structural design of functional blocks for memory execution pipes of high-performance microprocessors; conduct logic & circuit design of functional blocks; perform microarchitecture, circuit & logic design validation; conduct silicon debug & validation of microprocessor memory subsystems. Ph.D. in Electrical and/or Computer Engineering. Academic project/research background in: CMOS VLSI circuit & logic design, simulation, layout, validation & debug; VLSI CAD tools, including SPICE; high-performance computer architectures & design techniques, including multiple instructions per cycle computers, superscalar microprocessors, pipelined architectures, parallel architectures, memory hierarchy & cache design; Register Transfer Logic (RTL) model for high integration processor implementation; software development for VLSI design; C & UNIX. $4,600/mo.; 40 hrs./wk. Place of employment and interview: Beaverton, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550454, 875 Union Street, N.E., Room #201, Salem OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Lead Engineer to direct design/development/implementation/integration/testing of high freq. modem in HF Data Link Network Project; design/implement data comm. protocol. Design adv. modulation/demodulation techniques; develop models to simulate/test algorithms; analyze/develop signal processing algorithms; define firmware architecture; code software/firmware. Must have: Ph.D. (or proof of elig.) in Elec Eng, major in Digital Signal Processing or Comm. Theory; 2 yrs commercial/academic work exper. specifically designing comm. systems & implementing/integrating systems using C & Ti TMS320 assembly lang. on microprocessor-based hardware platform. Exper. must incl. work in Adaptive Digital Signal Processing/Signal Detection/Estimation/Error Correcting Codes. $57,500/yr; 40 hrs/wk; Redmond, WA. Send resume by 06/05/93 to Employment Security Dept., E&T Div., Job Order #358318, PO Box 9046, Olympia, WA 98507-9046.

Power Quality Engineer. An established, national manufacturer of electrical equipment in the power quality field seeks an electrical engineer to head its design/applications department. Candidates should have experience in design and manufacture of electrical equipment plus a familiarity with the analysis and issues specific to power quality including transients, sags, systems harmonics, RFI and EMI. Familiarity with drives is a plus. The recent high growth rate of the company requires an independent engineer who wants the freedom to set his/her own agenda. EE required; MSEE a plus. Furnish salary history with resume to: IEEE Spectrum, Box 5-2, 345 E. 47th St., N.Y., N.Y. 10017.

Dir. Lamp Engg: East Coast lamp mfgr. ($30mm annual sales). Req. BSEE or equiv. Min. 5 years exp. lamp engg. Responsible for new product development/sustaining engg. Staff of 10. Salary: low $60s. Send resumes to: IEEE Spectrum, Box 5-3, 345 E. 47th St., N.Y., N.Y. 10017.

Technical Manager - Geothermal Power Plant. Oversee all corporate & staff activities related to geothermal reservoir engineering & geoscience, geothermal engineering, electrical engineering & process analysis. Monitor reservoir & plant to ensure optimal performance. Respond to upsets at all contract facilities. Provide tech support & analysis for new business development. Prepare bid documents & assist in negotiations with: utilities; financial institutions; & equity partners. Requires: B.S. in Elect. or Power Eng. & 8 yrs. experience in job offered or 8 years exp. in design, development & maintenance of power plants. Demonstrated expertise in: substation & high voltage transmission design; geothermal reservoir analysis; well logging & interpretation; financial analysis & contract negotiations for power plant design & management; use of TOUGH numerical simulator & computer-based database systems; management of technical eng. staff. Must have legal right to work permanently in U.S. Job site Reno, NV. 40+hr/wk. Salary: $82,000/yr. Please submit resume and a copy of this ad to: S. Bauder, NV. Employment Security Dept., 70 W. Taylor St., Reno, NV. 89509-1700. Refer to # 9240939. Responses accepted no later than 5/25/93.

Scientist/Computational Scientist, Ames Laboratory. The Ames Laboratory is seeking a computational scientist to conduct research within the Applied Mathematical Sciences Program. The incumbent is required to have a demonstrated expertise in computer performance analysis. The incumbent will be expected to conduct research projects in conjunction with other staff members, postdocs and students. Minimum qualifications include a Ph.D. in an area of computational science. Experience must include use of parallel computer systems and supercomputer computation research. Work experience in an industrial setting is preferred. Competitive salary and benefits. Send cover letter, resume, plus the names and addresses of three references to: Ames Laboratory Personnel Office, 127 Spedding Hall, Iowa State University, Ames, Iowa 50011. Application deadline of June 15, 1993, or until filled. An equal opportunity/affirmative action employer.

Software Designer: Design and maintain computer-aided-design and drafting for the Apple Macintosh and IBM (or clone) series of computers. Improve existing software systems as well as maintain existing software. Must be proficient in Apple 68000xx Assembly language. Must be familiar with Unix environments. Must have proof of legal authority to work in the U.S. Salary $38,500/yr for 40 hour work week. Masters Degree in Computer Science required. Submit resume and letter of application to Oklahoma State Employment Service, 219 NE First Street, Pryor, OK 74361 (ID #4900) Job Order #039527).

Magnetics Engineering Specialist. Engineer must have ability to provide technical leadership and analytical assistance to designers of magnetics for power electronics, work with designers on the implementation of advanced magnetics designs, and work independently to develop improved analytical tools and a magnetic materials database. Requires 10 years in magnetics materials and power electronics design including electromagnetic field theory and high frequency circuit and finite element modeling in the 100 KHz to 2GHz range; a demonstrated track record of accomplishment including published articles, patents and successful commercial implementations of leading edge technologies; and a technical Bachelor's Degree. Advanced study in fields applicable to magnetics design for power electronics preferred. ELDEC Corporation is a $100 million manufacturer of electronic components for aerospace. We are an Equal Opportunity/Affirmative Action Employer. Send resume to David Neils, ELDEC Corp., P.O. Box 100, Lynnwood, WA 98046.

Semiconductor manufacturer seeking DRAM Designer with strong Solid-State Device background. Will lead development of silicon carbide semiconductor memories. Requires thorough knowledge of device physics as well as DRAM cell and peripheral circuitry design. Experience with both MOS and bipolar design and advanced degree desired. EOE. Qualified candidates should send resume to: Human Resources Department, Cree Research, Inc., 2810 Meridian Parkway, #176, Durham, NC 27713.

Applications sought for industrial research scientist position. Need creative self starting person with experience in electronic device design. Knowledge of HTS & their electronic applications helpful. PhD or off setting experience in EE or physics required. Apply to MSI, 1321 Wakarusa Dr. STE 2104, Lawrence, KS 66049.

Government/Industry Positions Wanted

Math M.S. 25 years R&D, pubs guid waves sys seeks 2-4 mo pos Num Meth-coding Macsyma/HT Basic PC486 (602)574-2516.

M.S. EE seeking ASIC design position. 3+ yrs. working exp. comprehensive knowl. & hands-on exp. in mixed-mode ASIC design. Proficient in Hspice, verilog, Cadence. Reply: P.O. Box 677, College Station, TX 77841-0677.

PROFESSIONAL CONSULTING SERVICES

Editorial Offices: New York City 212-705-7555 San Francisco 415-282-3608 Washington, DC 202-544-3790

EDITORIAL CORRESPONDENCE. IEEE Spectrum, 345 East 47th St., New York, N.Y. 10017, Attn: Editorial Dept. Responsibility for the substance of articles published rests upon the authors, not the IEEE or its members. Letters to the editor may be excerpted for publication.
REPRINT PERMISSION. Libraries: Articles may be photocopied for private use of patrons. A per-copy fee (indicated after the code appearing at the bottom of the first page of each article) must be paid to the Copyright Clearance Center, 29 Congress St., Salem, Mass 01970. *Instructors:* Isolated articles may be photocopied for noncommercial classroom use without fee. *Other copying or republication:* Contact: Editor, *IEEE Spectrum.*
ADVERTISING CORRESPONDENCE. IEEE Spectrum, 345 East 47th St., New York, N.Y. 10017, Attn: Adertising Dept., 212-705-7760. Also see Advertising Sales Offices listing on last page. The publisher reserves the right to reject any advertising.
COPYRIGHTS AND TRADEMARKS. IEEE Spectrum is a registered trademark owned by The Institute of Electrical and Electronics Engineers, Inc. At issue, EEs' tools & toys, Faults & failures, Innovations, Legal aspects, Managing technology, Newslog, Program notes, Reflections, Speakout, Spectral lines, Spinoffs, Technically speaking, The engineer at large, and Whatever happened to? are trademarks of the IEEE.
GENERAL INQUIRIES: 1-800-678-IEEE; Headquarters: 345 East 47th St., New York, N.Y. 10017, 212-705-7900. *Tel. extensions at headquarters:* General Manager, 7910; Public Relations, 7369; Publishing Services, 7560. *At other locations:* Regional Activities, Section Services, Educational Activities, 908-981-0060. Or write to IEEE Service Center, Box 1331, Piscataway, N.J. 08855; Membership Services, 908-981-0060; Professional Services, 202-785-0017; Technical Activities, 908-562-3900.

Scanning
The Institute

Rising incomes stay ahead of inflation

The IEEE's 1993 salary survey shows that the purchasing power of members working full time has risen slightly since the last biennial survey conducted in 1991. The median income from the engineers' primary area of technical competence rose to US $61 061 from $58 000 in 1991.

The survey also showed that involuntary unemployment reached 2.7 percent in 1993. The previous high was 1.7 percent in 1975.

Some 6640 members responded to this latest U.S. Membership and Fringe Benefit Survey, conducted on behalf of IEEE–U.S. Activities by Westat Inc., Rockville, Md. The survey was sent to 20 979 randomly selected U.S. members.

The survey report, available May 15, sells to members for $74.95, to nonmembers for $119.95, plus tax, postage, and handling. Contact the IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 1-800-678-IEEE.

Style file on e-mail

The IEEE's publishing staff has developed a special style file, called "IEEEtran. sty", which is available to any prospective author who e-mails a request to "help @ep.iee.org".

When submitting electronic manuscripts in TeX or LATeX, remember to:

• Include all macros (referred to as /def) needed to produce a document.

• Remember that IEEE transactions style dictates a 21-pica (3.5-inch) column width. Mathematical expressions produced with this in mind look more attractive.

Board meeting almost paperless

The IEEE Board of Directors met for the first time this year on March 2 in Chicago. It was an almost paperless affair. All agenda items were contained on a 3 1/2-inch diskette instead of on sheets of paper in weighty binders. The agenda itself was available on a sheet of paper for reference.

Some 40 attendees followed the proceedings on 25-MHz, 386-based laptops with an 80-megabyte hard drive, a diskette drive, and a fax modem. With nickel cadmium batteries, the units weighed about 4 kg.

Being considered for the future; networking laptops, and using groupware for activities like brainstorming, and decision-making discussions.

Sections Congress '93

Chapter and Section leaders should be preparing to attend the triennial Sections Congress, the Institute's only meeting of local volunteers from all 10 IEEE regions. The meeting, under the banner "Empowering Sections to Serve Members," takes place July 1–4 in San Juan, Puerto Rico.

For additional information, members should contact Susan Sacks, Coordinator, Sections Congress '93, IEEE Field Services, Box 1331, 445 Hoes Lane, Piscataway, N.J. 08855-1331. 908-562-5512; fax, 908-463-3657; e-mail, "s.sacks @ieee .org"; Telex, 833233.

Coming
in Spectrum

NONSTOP COMMUNICATIONS. New wireless services allowing universal access to the telephone, as well as data communications and networking, are on the drawing boards of leading vendors and communications planners worldwide. Decisions over frequency allocation and system architectures have to be made, as well as how best to avoid interference.

NEURAL NETWORK USES. Inspired by research on the human brain, these data classification and pattern recognition systems often capture subtle relationships that defy mathematical or other formulation. Applications are emerging fast.

VHDL—PANACEA OR HYPE? In its fifth update, this standard hardware description language for very high-speed ICs should provide a universal means for describing electronic circuits worldwide. But still missing is a modeling standard.

CELLULAR PHONES AND CANCER. Despite the media frenzy, there is no evidence that radiation from cellular phones causes health problems. The Food and Drug Administration sees no reason to regulate the devices, and the IEEE has no plans to change its C95.1 standard. Nevertheless, manufacturers are striving to minimize power output (a good thing because it extends battery life), and more studies are under way.

EARTH WOES. The production of goods for human consumption always depletes natural resources, uses energy, and creates pollutants. These problems will only worsen as China, India, and South America approach the West's level of industrialization. What can IEEE members do about it? A good first step might be to assist in defining the problems.

MICRO ENERGY STORAGE. After years of research into multimegawatthour storage for utilities, smaller superconducting magnetic-energy storage systems are becoming available to provide backup power for such critical industrial processes as semiconductor chip testing. Early implementations look promising.

ADVERTISING SALES OFFICES

345 East 47th Street, New York, N. Y. 10017

William R. Saunders	Advertising Director	212-705-7767
Michael Triunfo	Northeastern Manager	212-705-7312
Dawn Becker	New York Manager	212-705-7311
Hendrik Prins	Research Manager	212-705-7067
Theresa Fitzpatrick	Advertising Production Manager	212-705-7579

Boston, MA–Doug Long,
46 Main St., P.O. Box 2780, Orleans, 02653 508-255-4014

Chicago, IL–Ralph Bergen,
One Northfield Plaza, Suite 300, Northfield, 60093 708-446-1444

San Francisco, CA–Denis F. Duffy,
3755 Balboa Street, Suite 201, 94121 415-386-5202

Los Angeles, CA–Lynne Andrew Evans,
5757 West Century Boulevard, #700, 90045 310-649-3800

Atlanta, GA–H. Michael Coleman, C. William Bentz III,
4651 Roswell Road N.E., 30342 404-256-3800

Denver, CO–David B. Schissler,
32570 Aspen Meadow Drive, Evergreen, 80439 303-670-3749

Dallas, TX–Matt Kincaid, Eric Kincaid,
9794 Forest Lane, Suite 634, 75243 214-553-9896

Tokyo, Japan–German Tajiri,
IMI Corp., Saito Lend Bldg., 13-5, Ginza 3-chome, Chuo-ku,
Tokyo 104. (03) 3546-2231. TELEX: J23449 (IMI TOKYO)

Munich, Germany–Ric Bessford, Leopoldstr. 52,
8000 Munich 40, Germany, 49-89-39-00-55

Publisher: Allan Wittman
Administrative Assistant: Nancy T. Hantman
Associate Publisher: William R. Saunders (Advertising)
Administrative Assistant: Christine Demchak
Vice President, Publications: Helen M. Wood

ADVERTISERS INDEX

Circle numbers on the Reader Service Card, opposite page 86, that correspond to the advertisers listed below. *Advertiser in North American edition. **Advertiser in North American Exact edition.